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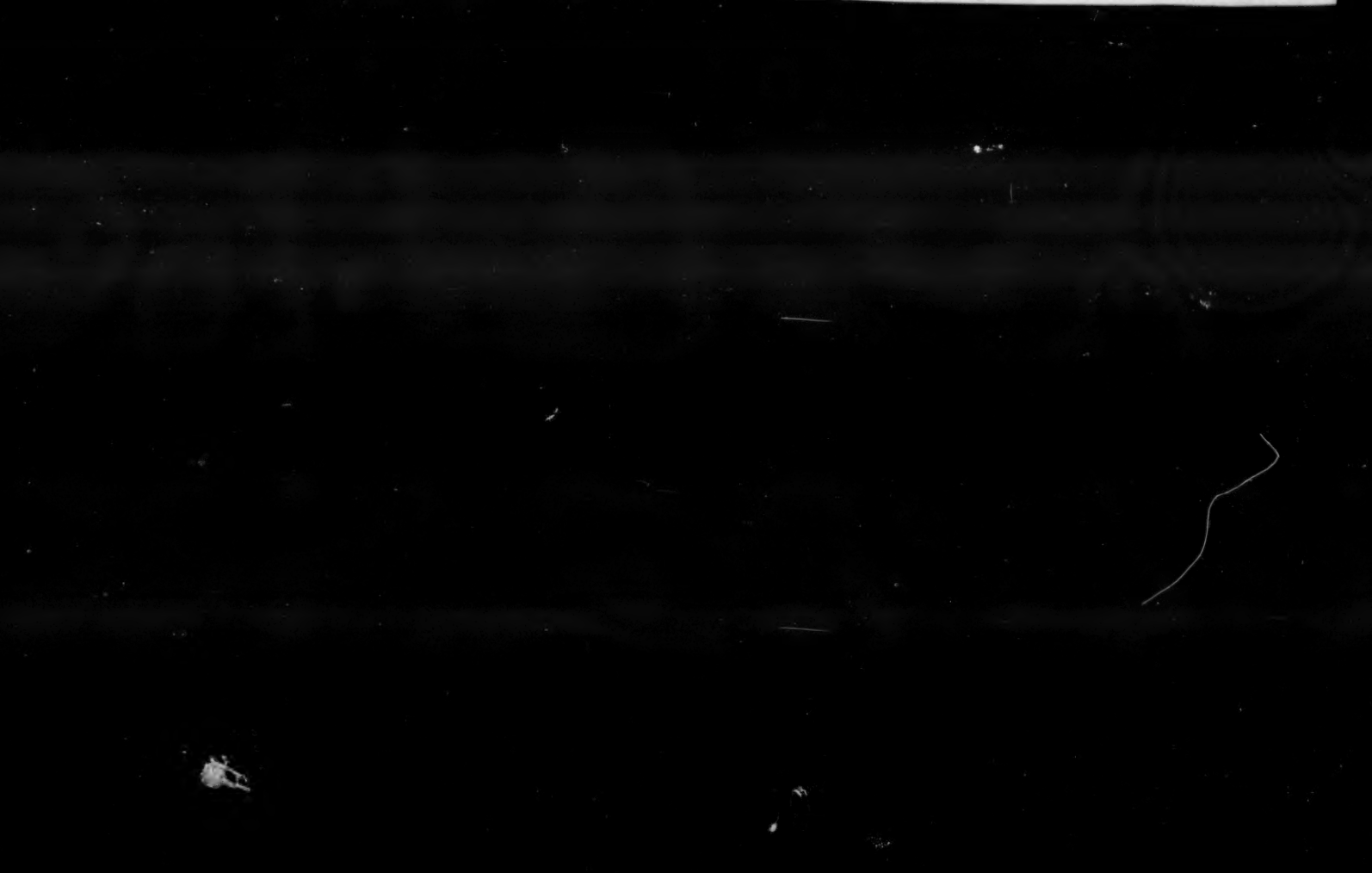


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIV. — *An experimental investigation of the equilibrium of the forces acting in the flotation of disks and rings of metal: leading to measures of surface tension;* by ALFRED M. MAYER.

IT occurred to me that if a ring of metal with a chemically clean surface could be floated, and then gradually weighted till it broke through the surface of the liquid, one might thus directly measure surface tension. At the time I saw little prospect of succeeding in floating a ring with a clean surface, for all the treatises on physics I had read state that to float a metal on water its surface must be coated with a film of grease. A ring of aluminum seemed the more likely to float because this metal has a peculiar repellent action on melted alloys, like ordinary solders. I made a ring of aluminum 50^{mm} in diameter out of wire 1^{mm} thick. It floated on water. As I gradually added weight to the ring (see fig. 4) it sank deeper and deeper in a depression in the water, till having reached a depth of 5^{mm}, it broke through the water-surface. The total weight required to make the ring break through the surface was 2·6 grams.

In subsequent experiments I floated a ring of $61{\cdot}8^{mm}$ in diameter made of aluminum rod $3{\cdot}7^{mm}$ ($\frac{1}{6.8}$ in.) in diameter. This ring weighed 5·8 grams. To float this ring requires a steady hand and patience; but a ring made of aluminum rod $3{\cdot}15^{mm}$ ($\frac{1}{8}$ in.) in diameter is easily floated. With this ring may be made an interesting experiment. The ring with fine wire yoke and cup (see fig. 4), weighs 4·435 grams. One gram added to the ring causes it to sink, giving 5·435 as the breaking weight. The unloaded ring therefore weighs 19 per cent

less than the breaking weight. If from any cause, such as the gathering of dust on the water, or, the contamination of its surface from the vessel holding it, the surface tension should be weakened 19 per cent, then the unloaded ring will sink. This weakening of the surface tension is readily and rapidly brought about by pouring vapor of ether on the water. When this vapor reaches the water the ring moves to and fro in a tremulous manner and then sinks.

In my ignorance, I saw in these experiments a property of flotation peculiar to aluminum. Experiment, however, soon showed me that all metals, with clean surfaces, from platinum of a density of 21·5 to magnesium of a density of 1·7, float on water. When and with whom originated the erroneous statement, that metals to float must have their surfaces greased, I have not been able to discover; but this error has been copied from one treatise on physics into another for about a century. The older writers, and those who in recent times have published papers on their studies of these phenomena, make no mention of the necessity of greasing a metal to make it float.

In his "History of Physics"* Poggendorff states that "Norman (he who discovered the dip of the needle) showed Gilbert that a needle placed carefully on water floats, and if magnetized points constantly in one direction." Poggendorff does not give his authority for this statement. Gilbert in his "De Magnete," 1600, does not say that Norman floated a metal *per se* on water. He thus describes Norman's experiment: "Norman proves his theory as follows: Take a round vessel full of water; on the mid surface of the water float a small bit of iron wire *supported by just as much cork as will keep it afloat* while the water is in equilibrium: the wire must have been first magnetized so as to show plainly the variation point D. . ."† It may be that Norman's experiment of floating a needle is described in his "New Attractive," 1596, a very rare work, which I have not been able to consult.

"The observation of Norman, that a steel needle placed carefully on water floats, led Borelli, 1655, to study more minutely this phenomenon. He procured two little sheets of brass, and placed them with care on water, where they floated. By means of rods he pushed them towards one another, and saw that when they had approached sufficiently, they mutually attracted."‡

Descartes in "Les Météores," Leyden, 1638, says:§ "La superficie de l'eau est beaucoup plus malaysée a diuiser que

* Histoire de la Physique, Paris, 1883, p. 170.
† "De Magnete." Translation by P. Fleury Mottelay, p. 244. N. Y., 1893.
‡ Poggendorff: Hist. de la Phys., p. 249.
§ I give this quotation in the orthography of his time.

n'est le dedans, ainsi qu'on void par expérience en ce que tous les corps assez petits, quoyque de matière fort pesante, comme sont de petites aiguilles d'acier, peuvent flotter et estre au-dessus, lorsequ'elle n'est point encore diuisée, au lieu que lorsqu'elle l'est ils descendent iusque fonds sans s'arrester."

The next paper on the subject is by "M. Petit le Mèdecin," published in the Memoirs of the Academy of Sciences, Paris, 1731, in which the author states that the reason why a metal floats on water is that it is kept from touching the water by a film of air which coats the surfaces of all metals. I think that M. Petit makes good his statement, for he shows that on heating a metal it no longer floats, but sinks. He makes no mention of having previously greased the wires and sheets of metal with which he experimented.

Rumford, in 1807, published a paper in the Memoirs of the Academy of Sciences, of Paris, in which he attempts to show that a film of air does not exist on floating metals. I do not think that he makes good his opinion, for the only experiments he makes to sustain it are those in which water is covered with ether, with turpentine, or with olive oil, and small spheres of tin and of mercury, allowed to fall through the supernatant liquid, are retained by the surface of the water, which takes the form of sacs, that support and partly inclose the spheres.

In 1824 Pichard,* engineer in the French army, thus explains the floating of a needle. If the needle be not wetted then it sinks in a depression of the surface of the water, and the vacant space caused by this depression together with the needle forms a float. When the specific gravity of this, as a whole, is less than that of the liquid, its weight will be insufficient to overbalance the upward hydrostatic pressure of the liquid, and it will float upon the surface of the latter. He then refers to the existence of an elastic pellicle, as held by some, and to that of the adherent layer of air as held by others, but does not adopt either, or propose any explanation of his own other than that of the compound float formed by the needle and the empty space around it from which the water has been displaced.

Gaillieron,† in a letter to De la Rive, after referring to the opinion of some physicists that a film of air adhering to the floating body is the cause of the depression made by it in the surface of the liquid, says: "This explanation is hypothetical, not even reaching a high degree of probability. It is therefore permissible to advocate another explanation, that of Count Rumford, defining once for all what is understood by pellicle."

* Considérations sur les phénomènes que présentent de petites aiguilles à coudre, posées doucement et dans une situation horizontale, sur la surface d'une eau tranquille. Biblioth. Univ., t. xxv, p. 273.

† Sur les movements de certains corps flottants sur l'eau. Bibl. Univ., vol. xxvi, p. 190, 1824.

But his definition is faulty. It is simply that a molecule of water at the lowest part of the floating body draws the neighboring molecule with it, this a third and so on. "The cohesion which unites all the molecules of the surface of the water forms a kind of pellicle, and there results a sac at the bottom of which the heavy solid rests."

In a second paper Gaillieron* gives an account of further experiments. He places a layer of oil upon the water, and drops the needle gently into it. It descends to the surface of the water. On looking upward at it through the glass, one sees, not the surface of the needle, but only the surface of the oil depressed by it. He explains these experiments by means of the existence of a pellicle.

De Maistre† (1841), after describing the floating of metals on the surface of water, says: This remarkable phenomenon is due to the fact that the molecules which form the surface of water have a force of mutual attraction greater than in the interior of the liquid. He then goes on to deduce the radius of activity of the molecular forces by studying the case of a drop of water formed at the end of a glass rod. The largest drop he could obtain had a radius of $1\frac{1}{4}$ line, and he supposes the size of the drop to be determined by the molecular attraction, which he therefore regards as acting effectively up to a distance of $1\frac{1}{4}$ line. At the close of his paper he quotes Rumford as having occupied himself with the peculiar properties of the surface of a liquid, and as having explained them by the supposition of a pellicle, the existence of which he considers to be proved.‡

"M. Artur, in his *Théorie élémentaire de la Capillarité*, Paris, 1842, is led from theoretic considerations to regard the superficial layer of all liquids as having a greater density and greater cohesion than exist in the interior, and therefore as having a certain resistance. Considering only the laws of hydrostatics, the volume of the depression formed in the surface of water by a floating needle should exceed by six times the volume of the needle, the density of steel being 7·8; but M. Artur and others have estimated the volume of this depression, and the highest valuation of it gives only three times the volume of the needle." §

In 1869 M. Leboucher‖ appears as the first physicist to study

* Bibl. Univ., vol. xxvii, p. 207, 1824.

† Notice sur la cause qui fait surnager une aiguille d'acier sur la surface de l'eau. Bibl. Univ., vol. xxxv. p 192, 1841.

‡ The foregoing extracts from the Bibl. Univ. were given me by Prof. Arthur W. Wright.

§ Taken from Plateau's "Statique expérimentale et théorique des liquides." 1873, vol. 2, p. 79.

‖ "Recherches expérimentales et théoriques sur un cas particulier de la théorie des corps flottants." Caen, Mem. Soc. Linn. de Normandie, XV, 1869, No. 2.

seriously the interesting phenomena presented in the flotation of metals. He is the first to make quantitative experiments. I have not been able to consult the volume in which his research appeared and all I have of his work is the abstract of it given by Daguin in his *Traité de Physique*, 1878, vol. 1, p. 277.

Leboucher floated on water thin plates of various substances and then loaded these gradually till they broke through the surface of the water. He then computes, e, the thickness a plate must have so that it will just *not* float. Knowing W, the total weight required to make the plate sink; d, the density of the substance, and s, the area of the plate, we have $W = s\,e\,d$. The value of e found for slate, mica, and brass is respectively $1{\cdot}5^{mm}$, 1^{mm}, and $0{\cdot}5^{mm}$.

To ascertain the upward hydrostatic pressure on the plate he measured the depth, h, of the bottom of the loaded plate below the general level of the water by means of a spherometer, the screw of which was brought in contact with the surface of the water and then with the surface of the plate. The spherometer rested on a horizontal annulus of glass placed on the rim of the vessel holding the water. Adding e to the depth measured we have h, and the upward pressure on the plate $= s\,h \times$ density of water.

Leboucher does not arrive at an equation of the forces acting on the floating plate, but states that the upward hydrostatic pressure on the plate is a little less than the weight of the plate; the difference is generally $\frac{1}{10}$ to $\frac{1}{5}$ of the weight of the latter; which he explains by the supposed existence of a capillary tension on the lower edge of the plate which is always slightly rounded. This tension acts with the upward hydrostatic pressure in balancing the weight of the plate. I shall recur to this opinion of M. Leboucher.

Equation of the forces acting in the flotation of a disk of metal.

Three forces are acting on a floating disk of metal (1) W = the weight of the disk; (2) P = the upward hydrostatic pressure on the bottom of the disk; (3) T = the vertical resultant of the surface tension of the water along the circumference of the upper edge of the disk. The relation of these forces is given by the simple formula

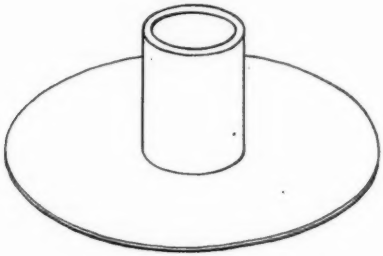
$$W = P + T$$

We can measure W and P, and $T = W - P$. Let circ = the circumference of the disk, then $A = \frac{T}{\text{circ}} \div \cos.$ angle of vertical with the depressed water surface at upper edge of disk; A

being the capillary constant, or surface-tension in grams per centimeter.

W is taken as the weight of the disk and superadded weight required to make the disk break through the water-surface. $P = a\ h\ d$, where a is the area of disk; h, the depth to which the bottom of the disk has sunk below the general level of the water at the moment it breaks through the water-suface, and d, the density of the water.

Fig. 1.



The manner of measuring W is as follows: A disk, fig. 1, has a hollow cylinder soldered or cemented to it. This cylinder is concentric with the circumference of the disk. The disk is floated on freshly distilled, clean water contained in a glass vessel, and the under surface of the disk is examined to be sure that no bubbles of air are adhering to it. Fine wind-blown sand, contained in a bottle provided with a bent tube of glass having a small aperture, is poured into the cylinder till the weight causes the disk to sink. The water has such a depth that when the disk has sunk the surface of the water is several millimeters below the top of the cylinder. The disk is now wiped dry and weighed. The water just used is rejected, replaced by clean water and the experiment repeated. The water is contained in a shallow cylindrical glass vessel, 16·5^{cm} in diameter. The edge of this has been ground flat so that the vessel may be closed by a glass plate and the water protected from dust till the moment when the disk is floated on it. The time which elapses from the moment the disk is floated till the load of sand causes it to sink averages 25 seconds.

The disks experimented on were made of aluminum. They were 1^{mm} thick and of various diameters. They were flat, and the cylindrical surface of the disk was quite smooth and polished. To accomplish this one must have a keen turning tool, and in turning the aluminum, it and the tool must be constantly supplied with petroleum. When finished the disks were cleaned

by first rubbing them with ether contained in a soft clean rag. The ether was then removed with absolute alcohol, and the latter with distilled water. The disk then remained under cover for an hour or more before experiments were made with it.

The depth, h, to which a disk went in the depressed water before it broke through its surface was measured as follows: A brass rod was turned so that it fitted neatly into the cylinder on the disk. This rod was attached to a slide moved by a micrometer screw in a vertical direction. The surface of the disk was carefully levelled. The disk was then screwed down till it just touched the surface of the water. That the plane of the under surface of the disk coincides with the plane of the water is known by examining the lower surface of the disk, when it will be found that if the plane of the disk is just in the plane of the water there is a uniform illumination over the surface of the water, but if the surface of the disk is the least below or above the surface of the water then the disk will be surrounded with a bright border. The disk is now lowered by the micrometer screw till it breaks through the water-surface. The instant that this happens is not as sharply marked as when the disk, free to move downwards, breaks through the surface from its weight, because the first intimation we have of the disk having reached the depth when rupture of the depressed surface takes place is that the latter begins to leave the sharp edge of the disk and to flow inwards over its surface. Hence h cannot be measured so accurately as W. This is shown in the tables of experiments on disk No. 1.

The measure of h given in the tables are the real depths to which the disk has sunk below the level of the water at the moment of rupture. It is evident that as the disk is depressed beneath the surface, the general level of the water in the vessel rises, and that the larger the diameter of the vessel the less the rise of the water, and consequently the less the error likely to be made in the computation. The vessel used in these experiments has a diameter of $16{\cdot}5^{cm.}$. By adding to the depression of the disk, as measured by the micrometer screw, the computed rise of the water in the vessel we obtain h.

The reason why we take W and h at the moment when the disk breaks through the surface of the water is that these quantities can be more accurately measured at the moment of rupture of the surface, and also at this moment W corresponds accurately with h.

Experiments on Disk No. 1. *Temp.* 18°.

Diameter of disk ..... 5·09^{cm}
Thickness of disk ..... 0·1 ^{cm}

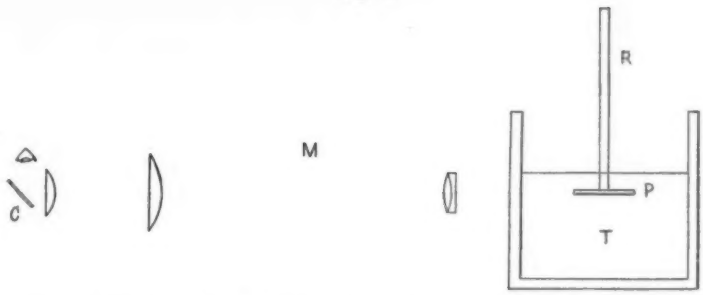
	W	h
1)	11·327 grams.	0·502 centimeter.
		·483
2)	·272	·507
		·489
3)	·333	·507 max.
		·500
4)	·335	·497
		·500
5)	·185 min.	·481 min.
		·505
6)	·287	·500
		·506
7)	·380	·500
		·489
8)	·276	·498
9)	·425 max.	0·497=mean.
	11·313=mean.	

In the experiments on W the mean of the difference of the maximum and minimum measures from the mean is ·12, and $\frac{\cdot 12}{11\cdot 318} = \frac{1}{94}$; while in the measures of h we have the mean of the difference of the maximum and minimum measures from the mean equal to ·013, and $\frac{\cdot 013}{\cdot 497} = \frac{1}{38}$. The knowledge of the upward hydrostatic pressure on the disk, so important in the deduction of the value of the tension from the equation $W=P+T$, seems to be uncertain, and it is not to be expected that experiments with disks can give accurate value of T.

On the form of the depressed water-surface.

To compute the tension in the plane tangential to the water-surface, along the circumference of the upper edge of the disk, it is necessary to know the angle that the depressed water, along this edge, forms with a vertical to this edge. The contour of the depressed surface was obtained in the following manner. A rod, R, fig. 2, was fastened at right angles to the plane of a square plate, P, of aluminum 0·1^{cm} thick. This rod

Fig. 2.



was fastened to the slide and micrometer screw used in determining h, and the plate of aluminum was brought down to the surface of the water contained in a tank, T, having sides of flat glass. The number of turns of the micrometer screw to bring the plate P to the depth of rupture of the water was ascertained. Then it was easy to depress the square plate in the water till it was just on the point of rupture. While in this position the edge of the plate was viewed in the microscope, M, provided with a camera lucida, C, and a drawing was made of the contour of the depressed water-surface. It is true that there must be some distortion of this contour, caused by refraction of the depressed water, but it is the only way by which I have been able to obtain even an approximation to the contour. The microscope objective, called a 3-inch, was of large aperture and of the low magnifying power of $11\frac{1}{4}$ diameters.

Fig. 3.

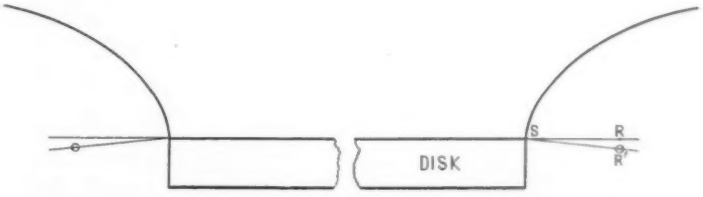


Fig. 3 is the average of several drawings of the contour. The engraving shows the disk, the depressed water and the contour of the latter, magnified $7\frac{1}{2}$ diameters. If the depressed surface met the edge of the disk normally, then the center of the radius of curvature of the lowest portion s, of the surface

would be at R, in the horizontal plane of the disk; but it was found to be at R′, so that R *s* R′ equalled 6°, thus giving 6° for the angle at *s* of the water-surface with a vertical to that point. Call this angle *d*.

We are now in possession of the facts pertaining to the forces acting on the floating disk. W and P are known and T=W −P. If the equation W=P+T be correct, then $\frac{T}{circ} \div \cos a$ should equal, or approximate, the value of A, the capillary constant, or, the surface-tension.

Data relating to disk No. 1, and value obtained for A.

Diameter of disk	5·09^{cm}
Thickness of disk	·1^{cm}
Circumference of disk	15·99^{cm}
Area of disk	20·348$^{sq\ cm}$
Density of water at 18°	·9986
W	11·313^{grhms}
h	·497

$P=ahd=20{\cdot}348\times{\cdot}497\times{\cdot}9986=10{\cdot}092$

$$A=\frac{W-P}{circ}\div\cos 6^\circ=\frac{11{\cdot}313-10{\cdot}092}{15{\cdot}99}\div{\cdot}9945={\cdot}07678$$

For disks No. 2 and No. 3 W and *h* were determined by series of measures similar to those make on disk No. 1. The departure of the minimum and maximum measures from the mean was about the same as obtained in the measures on disk No. 1.

Data relating to disk No. 2, and value obtained for A.

Diameter of disk	4·975^{cm}
Thickness of disk	·1^{cm}
Circumference of disk	15·63
Area of disk	19·438$^{sq\ cm}$
Density of water at 18°	·9986
W	10·885^{gram}
h	·495^{cm}

$P=ahd=19{\cdot}438\times{\cdot}495\times{\cdot}9986=9{\cdot}608$

$$A=\frac{W-P}{circ}\div\cos 6^\circ=\frac{10{\cdot}885-9{\cdot}608}{15{\cdot}63}\div{\cdot}9945={\cdot}08215.$$

Data relating to disk No. 3, and value obtained for A.

Diameter of disk	5·571^{cm}
Thickness of disk	·1^{cm}
Circumstance of disk	17·5^{cms}
Area of disk	24·38$^{sq\ cm}$
Density of water at 18°	·9986
W	13·739
h	·508

$P=a\times h\times d=24{\cdot}38\times{\cdot}508\times{\cdot}9986=12{\cdot}368$

$$A=\frac{W-P}{circ}\div\cos 6^\circ=\frac{13{\cdot}739-12{\cdot}368}{17{\cdot}5}\div{\cdot}9945={\cdot}07877$$

The values of A given by the experiments on the three disks are ·0767, ·0821, ·0787. The mean value is ·0791. The mean value of 28 determinations of A is ·0772. The value of A found from the experiments on the disks is so close to this value (only $2\frac{4}{10}$ per cent higher), that the formula $W=P+T$ seems to be the correct expression for the equation of the forces concerned in the flotation of a disk. However, I do not think that experiments on floating disks are of value in determining A, for the determination of the value of h, and consequently of P, is too uncertain. The maximum value of A obtained from the experiments on the disks is 7 per cent higher than the minimum and even this degree of concordance I regard as accidental.

It is seen that I do not agree with M. Leboucher in locating the upward action of the surface tension of the water along the *lower* edge of the disk, where M. Leboucher evidently regards the water as having a free surface; which it has not, as I shall subsequently show. I locate it on the free curved surface of the water above the upper edge of the disk.

If this upward pressure on the disk should be produced as M. Leboucher supposes, then this pressure will be nearly independent of the radius of curvature of the lower edge of the disk, for the area of this curved surface will vary as its radius while the capillary pressure will vary inversely as its radius. The capillary pressure $P=A\left(\frac{1}{R}+\frac{1}{R'}\right)$; where R is the radius of the curved edge, which we suppose variable, while R′ remains constant, varying very little from the radius of the disk; but $\frac{1}{R'}$ is so very small compared with $\frac{1}{R}$ that the value of P varies but little with various values of R.*

On the equation of the forces acting on a floating ring of metal, and on measures of surface tension obtained from experiments on floating rings made of various metals.

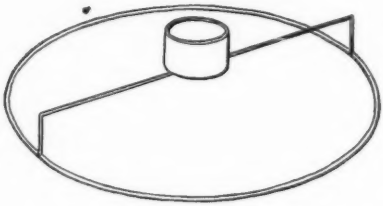
The floating ring presents more complicated, but more interesting phenomena, than those given by a floating disk. In the floating disk we have W and P quantities about ten times larger than T, and T is the vertical resultant of the tension acting along only one circumference; whereas in the case of the floating ring P is a small fraction, only $\frac{1}{14}$ or $\frac{1}{21}$, of W, and W is nearly equal to the vertical resultant of the surface-

* A drawing of the edge of disk No. 3 with a microscope and camera lucida gave $\frac{1}{20}^{mm}$ for the radius of curvature of the edge This makes $\frac{1}{R}=200$, while $\frac{1}{R'}$ is only 0·36.

tension along the lower borders of the two water-surfaces; one of these on the outer side, the other on the inner side of the axis of the ring. Thus while we cannot deduce a reliable measure of the surface tension from a knowledge of W and P in the case of the disk, we have conditions quite favorable to that measure in the case of the floating ring.

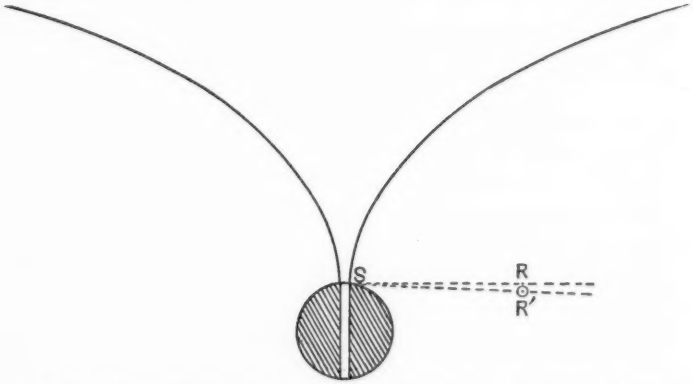
If a floating ring, fig. 4, formed of wire of 1^{mm} in diameter,

Fig. 4.



be gradually loaded by pouring fine sand into the cup carried by the ring, it sinks deeper and deeper into the depressed surface of the water till it has reached a depth of $0{\cdot}503^{cm}$, when it suddenly breaks through the surface and sinks.

Fig. 5.

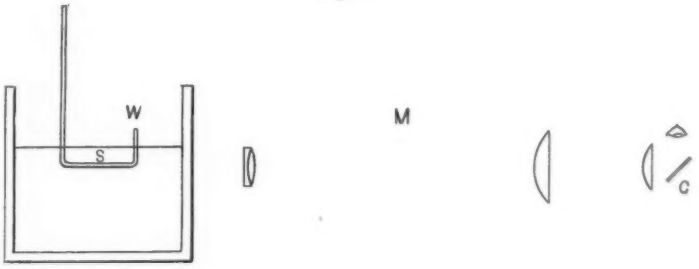


As the ring descends in the depression in the water, the latter incloses more and more of the ring till the opposite surfaces of the depression have approached to $\frac{1}{10}^{mm}$ as shown in fig. 5,

and the wire appears hung in an annular envelope of water supported by the two curved water surfaces. As the wire descends in the water these water surfaces always meet the wire as surfaces convex upward. When the two water-surfaces have approached it $\frac{1}{10}^{mm}$ as shown in fig. 5, the angle made by a water-surface with the vertical where it meets the wire at that point is $2\frac{1}{2}°$.

The contour of the depressed surface of the water, as I have drawn it, was obtained as follows: In a tank, fig. 6, with sides

Fig. 6.



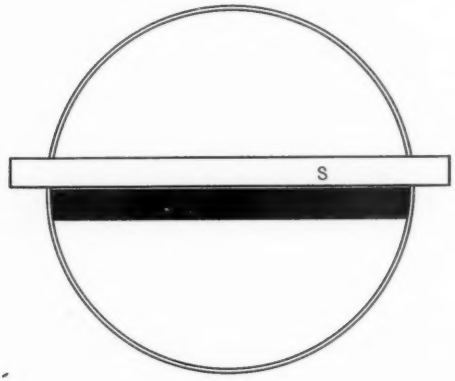
made of flat glass, a wire W, of 1^{mm} in diameter, bent twice at right angles, is brought down into the water by means of the slide and micrometer screw already described. It was found that this wire went to the same depth, $\cdot 503^{cm}$, before it broke through the depressed water as did a ring made of wire of the same diameter. A microscope, M, with a low-power objective, magnifying $11\frac{1}{4}$ diameters, is focussed on the wire at S. The leg, W, of the wire acts only as a kind of diaphragm to the objective and does not prevent one from having a sharp image of the depressed water-surface at S, though this point is directly behind the wire, W. Undoubtedly there must be some distortion in this image, caused by the refraction of the depressed meniscus of the water; but this method, used to obtain the approximately correct contour of the surfaces of the depression, is the only one I have been able to devise. With the camera lucida at C, several drawings were made of the contour of the surfaces. The one given in fig. 5 is formed by combining these drawings in an average curve.

The upper horizontal line shows the general level of the surface of the water. The bottom of the wire is $\cdot 503^{cm}$ below this level. The figure represents the phenomenon magnified 14 diameters. On this scale the depressed surfaces would meet the general level of the water at 21^{cm} on either side of the centre of the figure. If the radius of curvature of the portion

of the water-surface near the wire were at R, in the horizontal plane through S, then the curved surface where it meets the wire at S would be tangent to a vertical at that point. But the radius of curvature of this portion of the curved surface is at R', making R *s* R' equal to $2\frac{1}{2}°$ and showing that the vertical to S makes an angle of $2\frac{1}{2}°$ with the tangent to the curve at that point.

To determine the lateral extent of the depression of the water on either side of the wire of 1^{mm} in diameter, when it is just on the point of breaking through the water, the following method was used: On the top of a cylindrical vessel, holding water to within about 3^{mm} of its top, was placed a millimeter scale, S, fig. 7, 8^{mm} wide. On the upper surface of this scale

Fig. 7.



was cemented a slip of thin mirror glass with its plane inclined to the horizontal scale S, as shown in fig. 8. The top of the glass vessel was carefully levelled so that its plane was parallel to that of the water. On looking at the scale with the line of sight at the proper angle of incidence we see the scale directly, and in front of it the image of its lower surface reflected from the water. The off edge of this dark reflected image of the scale is made nearly to coincide with the near edge of the scale, so that a narrow, bright line is seen between the off edge of the reflection and the near edge of the scale, as shown in fig. 7. On now depressing the wire in the water, the surface of the latter is curved, and this surface curves the reflection of the edge of the scale. By sighting along the scale so that the pupil of the eye is seen reflected from the slip of mirror, at the point where the curved

Fig. 8

reflected edge of the scale becomes straight and parallel to the edge of the scale itself, we determine the extent of the depressed water-surface on either side of the vertical passing through the axis of the wire. This depression of the surface was found to extend to 15^{mm} on either side of the wire, when the latter was so deep that it was just on the point of breaking through the surface. I measured the area of the vertical section of this depression below the horizontal surface of the water and found it to be about 25 times the area of the cross-section of the wire.

The weight on one centimeter of a ring, formed of wire 1^{mm} in diameter, when on the point of sinking, is ·1696 gram, and the volume of one centimeter in length of the depression in the water, including the volume of the wire, if supposed to be formed of water, will weigh ·2 grams, or 20 per cent more than the weight on one centimeter of the wire.

Evidently the two opposite surfaces of the depression in the water made by the ring cannot be similar, as is the case in fig. 5, showing the contour of the surfaces on either side of the straight wire, for the curvatures of the water-surfaces in the horizontal and vertical planes on the outer circumference of the ring are opposed to one another, while these curvatures on the inner circumference of the ring have the same sign. It follows that $P=A\left(\frac{1}{R}-\frac{1}{R^1}\right)$ gives the molecular pressure of the outer and lower border of the surface of the depression, and $P=A\left(\frac{1}{R}+\frac{1}{R^1}\right)$, the pressure of the lower border of the inner surface. Assuming these pressures equal to the hydrostatic pressure, the radius of curvature on the vertical plane of the inner surface will be to the radius of curvature in the vertical plane of the outer surface as 1 : 1·162, as is shown in fig. 9.

Fig. 9.

Rings of wire 1^{mm} in diameter were made of iron, tinned iron, copper, brass and of german silver. The average diameter of the axes of these rings is $5{\cdot}35^{cm}$. The weight on a centimeter of the circumference of the axis of a ring required to make the ring sink, averaged, for the five rings, ·1696 gram.

Experiments on rings from 3 to 7·5 centimeters in diameter showed that, within these limits, the weight per centimeter of circumference required to sink the ring is constant, and therefore independent of the length of the circumference of the ring. The difference between the weight per centimeter required to sink the ring of 3^{cm} and the ring of $7{\cdot}5^{cm}$, as given by the experiments, amounted to only ½ of one per cent.

We now come to the consideration of the upward hydrostatic pressure on a ring at the moment the weight on the ring is sufficient to cause it to break through the water-surface. Fig. 5 shows a vertical section of a straight wire and of the contour of the depressed water-surfaces at or near the moment when the ring breaks through the water, and fig. 9 shows the section of the wire of *a ring* and the contours of the depressed water-surfaces. I say at or near the moment when the ring breaks through the water because, though I have made scores of observations on the upper surface of the ring between the two opposed sheets of depressed water, with a microscope provided with a micrometer eye-piece, I have not been able to decide whether the surfaces of fig. 5 and fig. 9 break near the ring when the surfaces have approached to $\frac{1}{15}^{mm}$, as shown in the figures, or whether these surfaces, as shown in fig. 10, come suddenly in contact the instant before the ring sinks. On some days I would rise from the microscope confident that the surfaces gave way before they came in contact; on other days I would be equally decided that they really met just as the ring went through the surface of the water. I am of the opinion that the latter condition is more likely to be true.

Fig. 10.

Evidently the upward hydrostatic pressure on the ring will differ in the two cases. Supposing that fig. 5 and fig. 9 give the real conditions at the moment of rupture of the water-film, then the upward hydrostatic pressure per centimeter on the ring equals the volume of one centimeter in length of the shaded portion of the section of the wire (see fig. 5), multiplied by ·9989, the density of water at 16°. To this is added the upward hydrostatic pressure or the area of $\frac{1}{10}^{mm}$ by 1^{cm} on the bottom of the wire. This equals ·01×·503×·9989, making ·01186 for the total upward pressure. But if the two opposed surfaces meet at the instant the ring sinks, as shown in fig. 10, we have for the upward hydrostatic pressure on one centimeter of the ring, ·00785^{cc}, the volume of one centimeter of the wire, × ·9989, the density of water at 16°; this equals ·00784 gram.

Determination of the surface tension of water from the experiments on the rings.

Let W = the weight required to make the ring break through the depressed water-surface; P = the upward hydrostatic pressure on the ring at the instant it breaks through the water; and T = the vertical resultant of the surface tension

along the lowest part of either of the depressed surfaces of water when these surfaces are nearly in contact, or in actual contact, and therefore when the circumferences of these surfaces may be regarded as equal to the circumference of the axis of the ring. Then,

$$W = 2T + P.$$

If we divide W by the circumference of the axis of the ring in centimeters we obtain, as the average of 30 experiments, ·1696 gram per centimeter. The upward hydrostatic pressure will be either ·01186 or ·00784 according as the two opposed films of water are as shown in fig. 9 or as in fig. 10. If as in fig. 9, then $A = \frac{\cdot 1696 - \cdot 01186}{2} \div \cos 2\frac{1}{2}° = \cdot 07895$. If as in fig. 10, then $A = \frac{\cdot 1696 - \cdot 00784}{2} \div \cos 2\frac{1}{2}° = \cdot 08095$.

A ring is formed by bending wire, 1^{mm} thick, around a cylinder or a cone, so that the axis of the ring shall be in a plane; in other words, so that the ring shall be flat. To obtain a flat ring is not easy, often only after several trials is it secured. Its ends are then neatly soldered together and the solder outside the juncture is carefully removed. Over a diameter of the ring is soldered a wire of $\frac{2}{15}^{mm}$ thick, raised above the plane of the ring as shown in fig. 4. On the top of this wire, and concentric with the circumference of the ring, is soldered a cup made of thin ($\frac{1}{4}^{mm}$) brass. The ring is now polished, and cleaned by the successive use of ether, strong alcohol and distilled water. After it has remained several hours under cover it may be experimented with.

The weight required to force the ring through the surface of the water is obtained by pouring into the cup of the floating ring a fine stream of sand issuing from a small smooth aperture in a bent glass tube which goes through a cork in a bottle containing the sand. This sand is from Minnesota. It is wind-blown, the grains being globular, or ovoid. It was passed through a sieve having 100 meshes to the inch. It is hardly possible to stop the running of the sand into the cup at the moment the ring sinks. From several experiments I estimated that on the average about three milligrams of sand were poured into the cup after the ring had really broken through the water, and this quantity was subtracted from the breaking weight of each experiment. Fresh distilled water was used in each experiment. On the average, each experiment occupied twenty-five seconds.

The depth to which a ring has descended in the depressed surface of the water at the moment the ring sinks was determined as follows: A ring of $5{\cdot}3^{cm}$ in diameter made of tinned

iron wire, 1^{mm} thick, was attached to the slide and micrometer screw already described in connection with the experiment on the disks. The following depths were measured. They are the depths given by the micrometer screw readings plus the computed elevation of the water in the vessel caused by the depression of the ring in the water-surface.

1) ·507^{cm}
2) ·502
3) ·503
4) ·503
5) ·500
6) 503

·503=mean

Experiments on the rings.

Let circ′= the circumference of the axis of a ring; then $\frac{W}{circ'}=w=$ the breaking weight per centimeter of circumference of the ring. Let p = the upward hydrostatic pressure on one centimeter of the ring. For p we take ·00784, supposing that the two opposite depressed surfaces of the water meet at the instant the ring sinks. Let A = the surface tension of water in grams per centimeter.

Experiments on the ring of Iron.

Diameter of axis of ring ..... 5·455
Circumference " " ..... 17·137
Temp. of water 16°.

W

2·866 min.
·891
·871
·886
·884
·894 max.

2·882=mean.

$$\frac{W}{circ'}=\frac{2\cdot882}{17\cdot137}=\cdot16817=w$$

$$A=\frac{w-p}{2}\div\cos 2\tfrac{1}{2}=\frac{\cdot16817-\cdot00784}{2}\div\cdot999048=\cdot08023$$

Experiments on ring of tinned Iron.

Diameter of axis of ring ..... 5·308
Circumference " " ..... 16·675
Temp. of water 16°.

W

2·817 min.
·838
·848 max.
·830
·841
·820

2·832 = mean.

$$\frac{W}{circ'} = \frac{2{\cdot}832}{16{\cdot}675} = {\cdot}16982 = w$$

$$A = \frac{w-p}{2} \div \cos 2\tfrac{1}{2}^\circ = \frac{{\cdot}16982 - {\cdot}00784}{2} \div {\cdot}999048 = {\cdot}08107$$

Experiments on ring of Copper.

Diameter of axis of ring ..... 5·46
Circumference " " ..... 17·153
Temp. of water 16°.

W

2·920
·914
·913 min.
·928 max.
·928
·926

2·9215 = mean.

$$\frac{W}{circ'} = \frac{2{\cdot}9215}{17{\cdot}153} = {\cdot}17035 = w$$

$$A = \frac{w-p}{2} \div \cos 2\tfrac{1}{2}^\circ = \frac{{\cdot}17035 - {\cdot}00784}{2} \div {\cdot}999048 = {\cdot}08132$$

Experiments on Brass ring.

Diameter of axis of ring ..... 5·183
Circumference " " ..... 16·283
Temp. of water 16°.

W
2·781 max.
·759 min.
·767
·765
·762
·761
2·7658

$$\frac{W}{circ'} = \frac{2{\cdot}7658}{16{\cdot}283} = {\cdot}16985 = w$$

$$A = \frac{w-p}{2} \div \cos 2\tfrac{1}{2}° = \frac{{\cdot}16985 - {\cdot}00784}{2} \div {\cdot}999048 = {\cdot}08107$$

Experiments on ring of German Silver.

Diameter of axis of ring ..... 5·382
Circumference " ..... 16·908
Temp. of water, 16°.

W
2·863
·895
·861
·901 max.
·863
·856 min.
2·873 = mean.

$$\frac{W}{circ'} = \frac{2{\cdot}873}{16{\cdot}908} = {\cdot}16992 = w$$

$$A = \frac{w-p}{2} \div \cos 2\tfrac{1}{2}° = \frac{{\cdot}16992 - {\cdot}00784}{2} \div {\cdot}999048 = {\cdot}08111$$

The tables of experiments on these five rings show that the average difference of the mean of the minimum and maximum measures from the mean equals $\frac{1}{203}$ of the mean value of W.

The values of A, omitting the last decimal figure as of no significance, are as follows:

From experiments on	Iron ring	.....	·0802
" "	tinned Iron ring	...	·0810
" "	Copper "	...	·0813
" "	Brass "	...	·0810
" "	German Silver "	...	·0811
			·0809 = mean

The maximum value exceeds the minimum by 1·37 per cent. The mean difference of the minimum and maximum from the mean is $\frac{1}{181}$ of the mean.

From these experiments on the rings, and from the value of A deduced from them, it appears that $W = 2T + P$ represents the equation of the forces acting on a floating ring.

On the value of the constant of the surface-tension of water.

The mean of twenty-eight determinations of the surface tension of water in grams per centimeter, made by physicists during the past sixty years, is ·0772. Nineteen of these determinations were deduced from measures on the ascent of water in capillary tubes and give a mean value of ·0769. These vary from ·0747 by Quincke to ·0812 as determined by Simon. The latter is 8·7 per cent greater than the former. The remaining nine determinations of the twenty-eight were made by measurements on drops and bubbles, adhesion of disks, pendent drops, weight of elevated meniscus adhering to a rectangular plate, extent and time of oscillations of falling drops, wave length of ripples, and by direct measure of tension of a film of water acting on a suspended rectangular frame. These vary from Lenard's ·0740, obtained from observations on the extent and time of oscillations of falling drops, to Quincke's ·0827, deduced from measurements on bubbles and drops. Quincke's value is 11·7 per cent higher than Lenard's.

The surface tensions given are reduced to their value at 0° by Brunner's formula, and are taken from a paper by T. Proctor Hall, *New methods of measuring the surface tension of liquids*, Phil. Mag., Nov. 1893, in which paper a complete list of the determinations of the surface tension of water is given in dynes. I have reduced them to grams per centimeter by dividing by 980·9.

The value ·0809 given by my experiments on the floating rings is 3½ per cent higher than ·0772, the mean of all the determinations on the surface tension of water. However, Quincke* gives ·0827; Timberg,† ·0820; Weinberg,‡ ·0816, and Simon,§ ·0812.

* Pogg. Ann., cxxxix, p. 253.
† Wied. Ann., xxx, p. 545, 1887.
‡ Beibl., xvi, p. 496, 1892.
§ Ann. Chim. Phys., xxxii, p. 5, 1851.

On the determination of the surface tension of a solution of sodium chloride of a density of 1·2.

A wire of platinum $\frac{4}{16}^{mm}$ thick made into a ring 5·04^{cm} in diameter, and provided with a wire yoke supporting a brass cup, floats readily on water. If we ascertain the weight per centimeter required to force the ring through the surface of the water, and subtract from this weight the upward hydrostatic pressure on a centimeter of the ring we will have a quantity which, compared with a similarly determined quantity, when the ring is placed on the solution of sodium chloride, will give the relative surface tensions of water and of the solution. The following experiments were made with the ring on water:

Diameter of axis of ring	5·04^{cm}.
Circumference of axis of ring	15·83^{cm}.
Temperature of water and of salt solution	16°.

W.
2·248
·297
·291
·233
·285
·287
2·273 = mean.

$$\frac{W}{circ'} = \cdot14358 = w\,;\quad w - p = \cdot14233$$

The following were the results of the experiments made with the platinum ring on the solution of sodium chloride.

$$\frac{W}{circ'} = \frac{2\cdot538}{15\cdot83} = \cdot1603 = w$$
$$w - p = \cdot1603 - \cdot0016 = \cdot1587$$

Taking ·0772 as the surface tension of water, we have for the surface tension of the solution of sodium chloride $\frac{\cdot1587}{\cdot1423} \times \cdot0772 = \cdot0860$. Frankenheim* gives ·0840 at 19°, which reduced by Brunner's formula to 16° becomes ·0844.

A peculiar phenomenon was observed during the experiments to find the weight necessary to sink the ring in the sodium chloride solution. There was observed a gradual

* Cohäsionslehre, Breslau, 1835.

diminution of this weight in each successive experiment. After each experiment with the ring on the salt solution it was placed in distilled water, vigorously agitated therein for a minute or two, then placed in fresh distilled water for several minutes, wiped dry and allowed to remain for about fifteen minutes before another experiment was made. The following table gives the result of six experiments.

W
2·543
2·430
2·425
2·424
2·411
2·407

It was found that, if the ring after having been thoroughly freed of the salt solution was allowed to rest for a day, it recovered its primitive breaking weight. Thus an interval of a day existed between the following experiments.

W
2·543
2·541
2·530
2·538 = mean.

A similar diminution of W in each successive experiment, but of greater extent, was observed in six successive experiments on the salt solution with a tinned iron ring.

The only explanation of the phenomenon that has occurred to me is that the salt solution in each successive experiment takes off a portion of the air condensed on the surface of the ring and gradually brings it towards that condition of the ring when it is freed of air, as by heat, and does not float at all. But why it takes twenty-four hours to recover its primitive surface, whereas, after having been heated to redness it recovers it in a half-hour, I cannot explain.

Uses of the platinum ring in measures of the degree of contamination of the surface of water, and in experiments on contaminated water contained in the trough of Miss Pockels.

If the platinum ring be loaded to, say, one-tenth of the weight required to make it sink and then floated on freshly distilled water, it will sink when, from any cause, the surface tension of the water has been lessened ten per cent. The duration of flotation of the ring is variable. On one day it floated during only two hours; on another day it floated for 9 hours;

on another day 5 hours. The same ring loaded so that it lacked 30 per cent of the breaking weight floated during 66 hours. The contamination of the water seemed more rapid during dry, windy and dusty weather than during, or just after a rain. The contamination, however, also proceeds from the vessel, either of glass or of metal, holding the water, as shown by Miss Agnes Pockels of Brunswick, Germany.* I have not given any study to the causes of the contamination of a surface of water exposed in the open air, because the results with the ring, though curious, are of little value unless connected with other observations on the conditions of the atmosphere. It may be that a floating platinum ring may be of use in determining the relative amounts of dirt or dust in the air on different days; but to be used for this purpose one must first accurately find out how much of the contamination is due to the substance of the vessel by experiments make on water in the trough of Miss Pockels inclosed in an air-tight vessel.

Several pleasing experiments may be made with the platinum ring floated on water in the trough devised by Miss Pockels. This ingenious and simple invention consists of a trough of tinned iron 70^{cm} long, 5^{cm} wide, and 2^{cm} deep, filled to its brim with water. A strip of metal longer than the width of the trough is placed athwart the latter with the plane of the strip in a vertical position. The lower edge of the strip touches the surface of the water. By sliding the strip from the extreme end of the trough the contaminated surface of the water is made smaller and more contaminated on the side of the strip towards which this is moving, while the surface of the water on the other side of the strip has been swept clean and may be regarded as a clean surface. The platinum ring is floated on this clean surface and the weight required to sink the ring is determined. Now load the ring till its weight is less than the weight required to sink it by 10, 20, 30, etc., per cent. If the ring is now floated near one end of the trough while the strip of metal is slid along from the other end of the trough towards the ring, the surface of the water on the side of the strip toward the ring becomes more and more contaminated till its surface tension can no longer hold up the ring, and this sinks. Knowing the percentage of the breaking weight with which the ring is loaded and the fraction of the length of the trough to which the strip has been moved when the ring sank, we have the degree of contamination of the water of the trough before it was altered by the sliding strip.

There is no difficulty in obtaining a contamination surface. The surface of distilled water is contaminated soon after it has

*Surface Tension. A letter to Lord Rayleigh from Miss Pockels. *Nature*, March 12, 1891.

been poured into the trough; and no doubt was contaminated before it was poured from the bottle. If, however, a greater degree of contamination of surface is required it may be obtained by introducing into the water the point of a needle which has been coated with a thin film of oil, or, by scraping camphor over the surface of the water. A very thin film of oil, whose thickness Lord Rayleigh has fixed as equal to $1\frac{1}{2}$ millionth of a millimeter, or $\frac{1}{4\,0\,0}$ of the length of a wave of yellow light, is sufficient to stop the motions of minute, thin scrapings of camphor.* If the motions of the camphor, however, continue with the degree of contamination we have given the water, we can stop these motions by increasing the contamination on sliding the metal strip along the trough and contracting the contaminated surface. If the ring floating on this portion of the liquid is now loaded till it sinks, we have the means of knowing the diminution of the surface tension required to stop the motions of the camphor.†

If the ring is placed near one end of the trough and the strip of metal is slid from the extreme end of the trough towards the ring, but not near enough to it to cause such lowering of surface tension that the ring sinks, one will observe the ring to move slightly away from the moving strip. This is owing to the contamination of the surface being slightly greater, and the surface tension lower, near the side of the strip towards the ring than it is at a distance from the strip, near to and beyond the floating ring. The consequence is that the surface film surrounding the ring and beyond it contracts and carries the ring away from the strip. The strip now remaining stationary, we have a lower tension on the contaminated or ring side of the strip than on the other side, where the surface of the water is clean; therefore on sliding the strip backwards with a gradually increasing velocity over this clean surface, or, on removing the strip from the trough, the clean surface contracts and keeps on contracting till it has so stretched the contaminated surface that it covers uniformly the whole surface of the trough. The ring, hung in this surface which is being stretched, moves with it and is seen to go rapidly towards the other end of the trough.

Metals and glass float on water when the film of air condensed on their surfaces has been driven off by heat.

If platinum, gold, or silver wire of $\frac{4}{1\,0}$ mm in diameter is formed into a ring, heated to redness and when cold placed on

* On Foam. A lecture by Lord Rayleigh before the Royal Institution. March 28, 1890.

† I have been prevented from making this interesting experiment by a painful and long illness from which I have not yet recovered.

water, it sinks. If the ring is wiped dry, and then placed on the water, it sinks; but if wiped dry and exposed to the air for from 10 to 15 minutes it will float. Also, a ring of one of these metals which has been heated to redness and which has not been wetted will float after having been exposed to the air for about a half hour.

Wires of platinum, gold, and of silver of $\frac{4}{10}^{mm}$ in diameter, and wires of aluminum, copper, brass and german silver of 1^{mm} in diameter floated when gently placed on the surface of water by means of a fork made of fine wire. These wires were 5 cms. long. All of these wires sank after having been passed slowly to and fro six times in the lower part of a spirit flame, and recovered their property of flotation after they had remained from two to five minutes in the air.

Glass rods of $\frac{1}{2}^{mm}$ in diameter and 5^{cm} long behaved in similar manner to the wires. If a rod of glass recently drawn out in a spirit flame and just cold is placed on water it sinks. After a freshly made glass rod has remained exposed to the air for about 15 minutes it will float. If a recently made glass rod which has just sunk in water be withdrawn, wiped dry, and exposed to the air for from 10 to 15 minutes, it will float. These floating glass rods, however, do not, as in the case of the wires, give straight lines of demarkation, between the surfaces of the glass and the water. At some places the water wets and covers the glass, at others it does not wet the glass, and the lines of demarkation of the glass and water are jagged. This rod, placed vertically in the water, shows an ascending meniscus at the parts where it was wetted when floating and a depressed meniscus at the parts where it repelled the water. If a glass rod is sunk and then brought to the surface of the water and floated and this operation repeated several times, the rod becomes more and more repellent of water, and when depressed in the water-surface by a fine wire the lines of separation of the glass and water becomes almost straight and the rod acts like one of clean metal. The rod can now be depressed, by a fork of fine wire, to nearly 3^{mm} below the general level of the water. These experiments show how soon the surface of glass is contaminated by exposure to water and air, this contamination reversing indeed the attractive property of *clean* glass for water.

The experiments on the metals show that when their surfaces are freed of air they sink, and that after the film of air has recondensed on their surfaces they float. In other words, in the first case the metals are wetted and in the second they are not. Considering fig. 5, it is evident that the dry surface of the wire between the two opposite depressed surfaces of water could not exist if the water wetted the wire as it would wet a ring made of clean glass. At the same time, though the water does not wet the wire as water wets glass, yet the water

is attracted by the wire so that it adheres to it with such force that it can take the curvature required to withstand the inward hydrostatic pressure on the two depressed water surfaces. Another observation is of interest here. On observing the wire between the depressed sheets of water through a microscope, as in fig. 6, one does not see the opposite surfaces of the water gradually and smoothly slide over the wire and approach one another as the wire goes deeper and deeper in the depression, but the terminal edges of the depressed water surfaces leave the wire to approach one another in a series of jumps. These releases of the two edges of the water surfaces from the wire do not take place uniformly and simultaneously along the whole of these edges, but take place at many points irregularly distributed along the lines of demarkation of the wire and water.

The attraction existing between the wire and the water is shown by lifting a floating ring above the general surface of the water when the water adheres to the ring and may be lifted several millimeters. If the ring be lifted quickly we often obtain a catenoid of elevated water-film apparently a centimeter or more in height. When the elevated film breaks it generally forms into drops regularly spaced around the ring.

The film of air on the surfaces of the rings must be very thin, probably a small fraction of the radius of molecular activity which, according to Plateau and Quincke, is about $0{\cdot}00005^{mm}$, or $\frac{1}{20}$ of a micron, or about $\frac{1}{12}$ of the wave length of sodium light. If, however, the air be condensed on the metals to the same degree that oxygen is occluded by platinum black, the air film may have the density of water and its attraction may be of an order approaching that of the metal itself for water. This condition, which probably exists, renders futile the determination of the thickness of the air film by optical methods. Professor Wright, of Yale University, suggested to me to determine if total reflection took place from a water surface which was in contact with a surface of metal. I made the experiment in the following manner. A cubical vessel made of plates of glass, such as is used in Plateau's experiments on figures of oil in dilute alcohol, was about two-thirds filled with water, and a black cross on a white ground was seen by total reflection from the surface of the water. A floating disk of aluminum was moved till it came over the portion of the water from which the reflection had taken place. The reflection was destroyed by the presence of the disk and this destruction took place either with a disk whose surface was partly polished or with a disk whose under surface had been made of a non-reflecting grey by the action of caustic soda. This fact is interesting, but I do not see how it can give information even as to the limiting thickness of the film of air of whose condensation and index of refraction we know positively nothing.

Stevens Institute of Technology, Mar. 1897.

ART. XXV. — *Note on Computing Diffusion;* by GEO. F. BECKER.

DIFFUSIVE phenomena have become of great importance to geologists. As every one knows, Lord Kelvin's famous inquiry into the age of the earth is based on the diffusion of heat in a cooling globe of large radius. The modern theory of the differentiation of rock magmas also is founded on phenomena of molecular flow, the least complex of which is the simplest case of liquid diffusion. The diffusion of motion in a viscous fluid is subject to the same laws and is capable of geological applications. Possibly even the diffusion of current density in a homogeneous conductor may eventually be made to contribute to a knowledge of the earth's interior.

The computation of the simplest diffusive phenomena has a formidable appearance to most geologists, while to those who are mathematically inclined the reckoning appears inelegant and clumsy. It is probable that every one who has actually computed diffusions has seen how the subject could be simplified, but each appears to have shrunk from the trouble of setting the matter straight. I shall attempt to make the subject so easy that no geologist will hesitate to compute any case which may help him to frame a theory or to test an hypothesis.

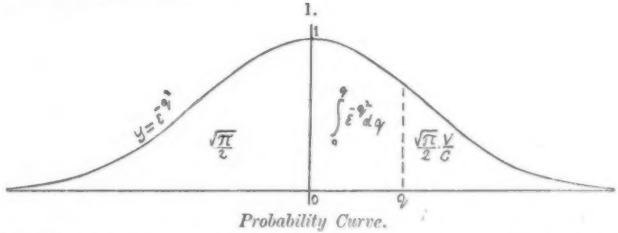
In "linear" motion as defined by Fourier the subject of motion, or the "quality" as Lord Kelvin calls it, varies only in one direction; in other words, it remains uniform at all points in any one plane at right angles to this direction. Qualities in this sense are for example the temperature of a body, the amount of substance in solution per unit volume, the velocity of a viscous fluid. For qualities obeying the law of diffusion the differential equation is

$$\frac{dv}{dt} = \kappa \frac{d^2v}{dx^2}.$$

Here v is the quality, t the time, x the distance from the plane of contact between the subject of diffusion and the medium into which it diffuses, and κ is the "diffusivity" assumed to be constant. The equation may be expressed by the statement that the time rate of change of quality is proportional to the space rate of the space rate of change of quality. It is usual with English writers to apply the C. G. S. system to these measurements. That system attains a most convenient uniformity, though only at the expense of some very awkward numbers.

The simplest case of linear diffusion arises when the diffusing quality at the initial plane is kept constant and when the

space into which it diffuses may be regarded as infinite. The quality at any distance measured perpendicularly to the initial plane is then proportional to the area of the "probability curve" taken between certain limits. Now this area between any limits has repeatedly been computed and tabulated, because it is of importance in the astronomical discussion of refraction, in the theory of probabilities, etc. Thus it is only needful to apply these tables to find the distribution of quality at any time or for any distance.



Probability Curve.

For this simplest case of diffusion let c be the initial concentration and let also

$$q = \frac{x}{2\sqrt{\kappa t}};$$

then the quality v in terms of the initial concentration is simply*

$$\frac{v}{c} = \frac{2}{\sqrt{\pi}} \int_q^\infty \epsilon^{-q^2} dq .$$

Here q appears as the abscissa of the probability curve. The value of the integral in this expression has been tabulated, but more usually it is the area from zero to q instead of that from q to infinity which is computed. That is a mere matter of detail; for the whole area from zero to infinity is simply $\sqrt{\pi}/2$, so that a knowledge of either part of the area leads immediately to the determination of the other. If the accessible tables have the usual form, it is only necessary to write the equation as follows:—

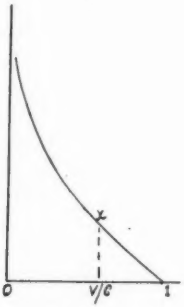
$$\frac{v}{c} = 1 - \frac{2}{\sqrt{\pi}} \int_0^q \epsilon^{-q^2} dq .$$

There is thus no mystery or difficulty about computing diffusion when κ is known. Of the three quantities x, t, and v,

* The truth of this theorem is easily tested; but its proof does not come within the scope of this note.

any two may be assumed and the corresponding value of the third found. The practical awkwardness of the results is a consequence of the fact that the tabulations are made with q for an argument. Hence, the least laborious method is to assume q at some tabulated even value, find x or t from the

2.



Diffusion Curve.

first of the above equations and v from the second. Thus assuming $t = 86400$ seconds (one day) and $\kappa = \cdot00001$, which is about the value for common salt, and taking $q = \cdot4$, one finds $x = 0{\cdot}7436$ and by the help of the tables of the integral, $v = 0{\cdot}5716\ c$. A series of corresponding values thus obtained for v and x is not easily grasped numerically. On the other hand, these values are readily plotted. It is apparently for this reason that Lord Kelvin has on various occasions represented diffusion by diagrams. Messrs. King and Barus used the same device, and the system of curves by the aid of which Lord Kelvin proposed the computation of diffusions* is mainly useful for the same reason.

The abscissa of the probability curve is not the natural independent variable for calculating diffusions. Greatly preferable is the quality, v/c. It is entirely possible to employ it in this way even with the tables hitherto published. The tables of the integral can be entered with rounded values of v, and corresponding values of q, containing as many significant places as desirable, can then be interpolated. From such values of q one can obtain x and the result is a table showing the distances for rational values of the quality. This, however, is a tedious process, since, for a satisfactory degree of accuracy, the interpolation must be made by second differences.

What is needed to facilitate computation of diffusions in a neat form, such as will not require diagrams to render the relations clear, is a table in which q, or better $2q$, is expressed

* Rep. Brit. Assoc., 1888, p. 571.

in terms of v/c. Such a table is given below, but only in skeleton for intervals of v/c of ·05. It will, I think, suffice for the needs of geologists, and it is hardly worth while to extend it to single hundredths unless some desire for such an extension should be manifested.* Knowing $2q$ for a stated value of v/c the value of x in centimeters follows easily from the equation,

$$x = 2q\sqrt{\kappa t}\,.$$

To find the distance at which any chosen quality exists in linear diffusion after the lapse of t seconds, it is now only necessary to add half the logarithm of κt to log. $2q$ and take the number corresponding to the sum from a table of common logarithms. This is a labor from which no geologist interested in diffusion can shrink.

The values of $2q$ are given in part because they are the distances in centimeters after the lapse of one particular time, that, namely, which is the reciprocal of the diffusivity. Thus in the case of salt with a diffusivity of ·00001, after a lapse of 100,000 seconds, or some 28 hours, $\kappa t = 1$ and $2q$ represents the distances answering to v/c.

If one is not anxious to preserve the severe simplicity of the C. G. S. system, the day or the year is a more convenient time unit than the second for computing diffusions of liquids as well as of heat in large masses of matter such as the earth. I have therefore tabulated δ as defined by the expression

$$x = 2q\sqrt{86400}\cdot\sqrt{\kappa\Delta} = \delta\sqrt{\kappa\Delta}\,,$$

where Δ is the time expressed in days; and also γ in

$$x = \delta\sqrt{365\cdot 2122}\ \sqrt{\kappa\Gamma} = \gamma\ \sqrt{\kappa\Gamma}$$

where Γ is the time expressed in years. To make the logarithms of $2q$ useful in this connection it may be noted that

$$\log\delta = \log 2q + 2{\cdot}46826\,;\ \log\gamma = \log 2q + 3{\cdot}74955.$$

In German papers it is usual to state the diffusivities of liquids in terms of days, so that if λ is the diffusivity thus stated $\lambda = 86400\,\kappa$ and

$$x = 2q\,\sqrt{\lambda\Delta}\,,$$

Of course the tabulated values of δ answer to a period for

* The values of q were computed from the seven-place table of the integral given by Lord Kelvin, Phys and Math. Papers, vol. iii, 1890, p. 434. The interpolations were made by a known formula of the same order of accuracy as the formula for second differences, and the results were tested by substitution in the formula for second differences. Seven-place logarithms were used. The abbreviation to five places introduces an apparent inaccuracy, inasmuch as the log $2q$, as tabulated, sometimes varies in the last place from the five-place log. of the tabulated value of 2q. The tabulated logarithms are, however, the nearest in five places to the values of $2q$ expressed in seven places.

which $\Delta = 1/\kappa$, or in the case of salt a period of 100,000 days, while the values for γ correspond for salt to a lapse of time of 100,000 years.

In connection with this table it may be convenient to set down a few diffusivities interesting to the geologist, either immediately, or for comparison with the diffusivity of rock magmas. The data for the diffusion of heat and motion are taken from Lord Kelvin's memoir on Heat. The diffusivities of solutions were all originally published in terms of days, not seconds. In the list below they are stated both in this way under λ and in seconds under κ. In choosing illustrations from the many experiments of Scheffer and of Schuhmeister* I have when practicable selected two nearly at the same temperature with different concentrations, and a third at a different temperature but with concentration as nearly as may be equal to that of one or other of the first two. There seems no doubt that κ in the case of liquids varies both with concentration and temperature. The variations of κ however, are far from complete elucidation.

Mr. Schuhmeister remarks that "the rapidity of diffusion runs almost exactly parallel with the larger or smaller values of the coefficient of friction," but makes no further comment on the relations of viscosity to diffusivity. In an investigation undertaken by Mr. A. Sprung† in Prof. Wiedemann's laboratory, for the purpose of determining the viscosity of salt solutions over wide ranges of temperature and concentration, diagrams and tables are given which enable one to fix the viscosities of seven salts of which Mr. Schuhmeister has determined the diffusivities for the same temperature and for nearly the same concentration. Sprung's concentrations are given in terms of the weight of anhydrous salt per 100 parts by weight of solution. Schuhmeister's data are for weight of anhydrous salt per unit volume of solution. The concentrations being 1/10 and the temperature 10° C., κ the diffusivity, and μ the coefficient of viscosity, the results of the two observers are expressed in the first three lines of the following little table.

Salt	KBr	KI	KCl	NaCl	$CaCl^2$	Na^2SO^4	$MgSO^4$
$\kappa \times 10^5$	13·08	12·96	12·73	9·72	7·87	7·64	3·24
μ	0·126	0·124	0·128	0·156	0·169	0·179	0·247
$\kappa\mu^2 \times 10^6$	0·207	0·199	0·208	0·236	0·224	0·244	0·198

* Mr. J. Schuhmeister's investigation, undertaken at Prof. J. Stefan's advice, appeared in Wien. Sitz. Ber. Ak. Wiss., vol. lxxix. 1879, Part II. p. 603. At the close of the paper mean values of λ are given for 10° C. Stefan recomputed Graham's diffusion experiments. His paper is in the same volume as Schuhmeister's, p. 161. Mr. J. D. R. Scheffer's memoir on diffusion is published in Verh. Kon. Ak. van Wet., xxvi. Part, 1888, with separate pagination.

† Pogg. Ann., vol. clix, 1876, page 1.

In the last line I have shown the product $\kappa\mu^2$, which evidently varies slowly and irregularly. Expressed in two figures the average of the two sulphates gives 0·22; the average of the three chlorides gives 0·22; the average of the five alkaline salts gives 0·22; the average for the seven compounds is 0·22. The average for the three potassium salts on the other hand is only 0·20, and the average for the two sodium salts is 0·24.

The variation of $\kappa\mu^2$ from a single value is perhaps not greater than might be expected from the data on diffusivity (which, as Mr. Schuhmeister himself points out, accord only approximately) if $\kappa\mu^2$ were really a constant. It is clear that the hypothesis—diffusivity is inversely proportional to the square of the viscosity for uniform temperature and concentration, expresses approximately the facts for these seven compounds. The number of compounds is small, but it embraces salts of four bases and of four acids showing rather a wide range of diffusivities and of viscosities. The probability that the accord is a mere coincidence seems to me extremely slight, and I infer that the hypothesis just stated probably expresses, at least roughly, the relations of diffusivity to viscosity for an important class of compounds. Should it prove that solutions such as rock magmas are to be included in this class, it would greatly facilitate the discussion of rock differentiation. Some approach to a quantitative determination of the viscosity of lavas might be attained. Direct investigation of their diffusivity would seem impossible.

Liquids diffusing into water.

Solution of	Temp.	Concentration.	λ.	κ	Authority.
Chlorhydric acid,	11·°	$1HCl/7{\cdot}17H^2O$	2·671	·000 030 91	Scheffer.
"	11·°	$1HCl/108{\cdot}4H^2O$	1·837	·000 021 26	
"	0·°	$1HCl/6{\cdot}86H^2O$	2·080	·000 024 07	
Sulphuric acid,	7·5°	$1H^2SO^4/685{\cdot}7H^2O$	1·042	·000 012 06	
"	8·°	$1H^2SO^4/36\ 2H^2O$	1·008	·000 011 67	
"	13·°	$1H^2SO^4/35{\cdot}4H^2O$	1·244	·000 014 40	
Sodium chloride,	7·7°	·147 85 g. per cm³	·810	·000 009 38	Schuhmeister.
"	8·3°	·322 38 "	·798	000 009 24	
"	14·°	·139 75 "	·9015	·000 010 43	
" (Mean),	10·°	·10	·840	·000 009 72	
Sodium carbonate,	5·5°	·099 86 "	·319	·000 003 69	
"	9·5°	·134 03 "	·375	·000 004 34	
"	20·5°	·182 42 "	·613	·000 007 10	
" (Mean),	10·°	·13	·390	·000 004 51	
Sodium sulphate,	5·3°	·046 19 "	·614	·000 007 11	
"	10·7°	·073 24 "	·678	·000 007 85	
" (Mean),	10·°	·10	·660	·000 007 63	
Copper sulphate,	8·1°	·177 64 "	·212	·000 002 45	
"	8·1°	·088 57 "	·230	·000 002 66	
"	4·6°	·129 26 "	·203	·000 002 35	
" (Mean),	10·°	·10	·210	·000 002 43	
Magnesium sulphate,	4·5°	·244 05 "	·209	·000 002 42	
"	9·4°	·309 92 "	·279	·000 003 23	
"	12 7°	·311 56 "	·305	·000 003 53	
" (Mean),	10·°	·10	·280	·000 003 24	
Cane sugar,	10·°	10 per cent	·456	·000 005 28	Graham;
Caramel,	10·°–11·°	10 per cent	·047	·000 000 54	Stefan.

Diffusion of heat and motion in C. G. S. units.

Subject of Diffusion.	Medium.	κ	Authority.
Heat,	Iron,	·225	Angstrom and Tait.
"	Sandstone,	·023 11	Forbes and W. Thomson.
"	Trachyte,	·010 28	Ayrton and Perry.
"	Trap,	·007 86	Forbes and W. Thomson.
"	Average of rock,	·01	" "
Laminar motion,	Air,	·053	Stokes and Maxwell.
"	Water at 10° C.,	·013 2	Poiseuille, Stokes.

Diffusion Table, giving distances in terms of quality, v/c, after the lapse of $1/\kappa$ seconds, days or years.

v/c	log. $2q$.	$2q$ in cm.	δ in cm.	γ in cm.
0·0	$+\infty$	∞	∞	∞
·005	0·59876	3·9697	1166·9	22300·
·01	0·56143	3·6428	1070·8	20464·
·05	0·44276	2·7718	814·74	15571·
·10	0·36664	2·3262	683·75	13067·
·15	0·30874	2·0358	598·40	11436·
·20	0·25825	1·8124	532·73	10181·
·25	0·21134	1·6268	478·19	9138·9
·30	0·16606	1·4657	430·84	8233·9
·35	0·12114	1·3217	388·50	7424·8
·40	0·07563	1·1902	349·85	6686·2
·45	0·02870	1·0683	314·02	6001·3
·50	9·97949—10	·95387	280·38	5358·4
·55	9·92704	·84536	248·48	4748·9
·60	9·87018	·74161	217·99	4166·1
·65	9·80734	·64172	188·63	3604·9
·70	9·73634	·54493	160·17	3061·2
·75	9·65381	·45062	132·46	2531·4
·80	9·55431	·35835	105·33	2013·1
·85	9·42725	·26745	78·615	1502·4
·90	9·24972	·17771	52·236	998·31
·95	8·94783—10	·08868	26·067	498·17
1·	$-\infty$	0·	0·	0·

Washington, D. C., February, 1897.

ART. XXVI.—*A relatively Acid Dike in the Connecticut Triassic area;* by EDMUND OTIS HOVEY.

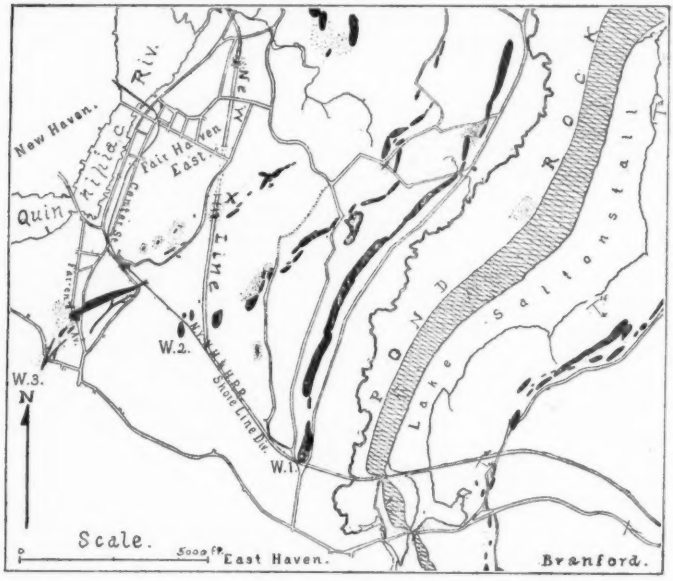
DURING the years 1893 and 1894 the New York, New Haven and Hartford Railroad Company made great changes in the layout of its Shore-line division, especially in the eastern part of the town of New Haven, Conn. Here it abandoned its old route entirely and cut its way through the Triassic sandstone by means of a deep trench and a long tunnel nearly half a mile east of its old course. For a considerable portion of the distance the new cut (50 feet deep in places) followed a shallow valley at the base of one of the low bluffs of sandstone which characterize the topography of the region. This proved to be one of the numerous fault planes of the district and the sandstone encountered was much broken and slickensided, so much so as to necessitate the lining of the entire tunnel with heavy brickwork. The cut revealed the presence of several dikes which are of some interest. All of them are transverse to the strike of the sandstone and the three largest (which are of ordinary diabase) and southernmost connect two of the ranges of dikes indicated on Percival's map* and shown in more detail on that published by the present writer,† a portion of which is reproduced here, with additions, as figure 1. The two smallest dikes as shown in the east wall of the cut coalesce in the floor, appearing as one in the west wall of the cut. The rock of these is different from the diabase of the region in chemical composition and structure, and approaches keratophyre, to which class it is provisionally referred. Slickensided surfaces in the middle of the largest dike (50 feet wide) show that some differential movements in the region have acted on the trap as well as the sandstone.

The relations of the dikes to one another and to the sandstone are so clearly indicated by the accompanying plan (fig. 3) and section (fig. 2) that extended comment on this feature is unnecessary. The dikes are seven in number, but Nos. 1 and 1*a* are evidently parts of the same; Nos. 2 and 3 probably meet a little east of the cut and Nos. 4 and 4*a* meet in the floor of the cut, so that the number of relatively independent dikes is four or, at most, five (see fig. 3). They vary in size from one or two inches up to about fifty feet, and extend in a belt about 440 feet wide diagonally across the railroad cut from northeast to southwest, the smallest ones being at the north and about

* Geol. Rept. of Conn., 1842, J. G. Percival. Reproduced in part in Dana's Manual of Geology. Fourth edition. p. 801, 1895.

† This Journal, III, xxxviii, pl. IX, Nov., 1889.

1.



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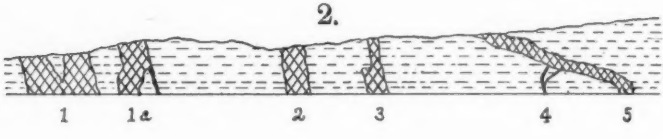

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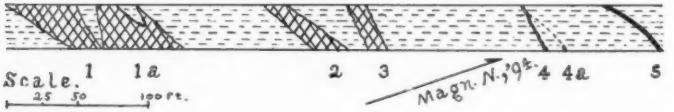


FIG. 1. Map of part of the towns of New Haven, East Haven and Branford, Conn. Solid black and cross-lined areas indicate exposures of trap; dots indicate sandstone associated with the trap. The dikes discussed in the present paper are located at X.

FIG. 2. Section of sandstone and trap as exposed in the west wall of the railroad cut at X, on the map. Scale as in figure 3.

FIG 3. Plan of floor of railroad cut at X, on the map. In this and the preceding figure sandstone is indicated by the broken lines and trap by the solid black and crossed lines. Horizontal and vertical scale the same.

110 feet from the southern entrance to the tunnel, which passes under East Grand avenue half a mile east of the Quinnipiac river. This is the best place near New Haven for the study of the phenomena of dikes: the differences in coarseness of grain in the dikes themselves on account of different widths; the increase in coarseness from each wall toward the center, especially in the larger dikes; columnar structure perpendicular to the walls in the heavy dikes; inclusion of country rock in the mass of a dike and the effect upon the igneous rock and the included block; contact phenomena on sandstone strata of varying nature, etc. Two-fifths of a mile north of the tunnel and a fourth of a mile from the Fair Haven station of the railway, an isolated dike crosses the cut. It is very irregular, from two to four feet wide, and trends N. 60° W. (magnetic) and hades 25° to 30° to the northeast. The course of the cut and tunnel is N. 18° E. (Observation made in October, 1894.)

The dikes which furnish the rock which is such a departure from the normal diabase of the region as to merit special description are numbered 4 and 4*a* on the plan, but 4*a* appears only in the east wall of the cut and although it is four or five inches wide at the level of the track, it pinches out about fifteen feet above, and does not reach the surface. In appearance it is like number 4 and is an offshoot from it. No. 4, from which the hand specimen about to be described was taken, is less than two inches (45^{mm}) wide at the level of the railway track on the east side of the cut and slowly and irregularly increases to about 8 inches in width toward the surface. The course across the bottom of the cut is about N. 80° W. (magnetic) and its hade on the east side of the cut is 33° to the south, but its inclination changes to the other side of the vertical on the west side of the cut and it passes very irregularly through the sandstone, separating into two branches as shown in the figure and being apparently intersected by No. 5. The color of No. 4 near the bottom of the cut on the east side is a light brick-red, very much like that of the inclosing sandstone but banded with different shades parallel to the sides of the dike and having small bluish green spots (chlorite) along the middle; green predominates above. On the west side the dike is grayish green with red edges. No. 4*a* is red. No. 5 is much wider than either of these, 3½ feet (1·1 meter), and its color and appearance are like those of the well known diabase dikes of the region: a very dense, greenish black rock with phenocrysts of augite. Under the microscope the rock of No. 5 presents a variation from the ophitic structure of typical diabase in that the augite of the groundmass is granular crystalline around the labradorite instead of being in broad plates penetrated by the feldspar. It is evident that dikes No. 4 and

4*a* cannot be offshoots from No. 5, on account of the difference in microscopical structure and mineralogical composition.

Petrography.—The hand specimen from dike No. 4 represents the whole breadth of the dike at the place from which it was taken and is from 4 to 4·5^{cm} wide. The texture is aphanitic at the sides and somewhat coarser in the middle, some of the larger feldspar phenocrysts and many areas of calcite and chlorite being discernible with an ordinary hand lens. Under the microscope the gradual increase in coarseness from wall to center is well shown. The rock consists essentially of feldspar. There are two sets of phenocrysts of feldspar. One is made up of relatively large tabular, cuboidal and lath-shaped twinned crystals which tend to form groups of twos and threes. The angles of extinction measured on the twinning trace, 18° to 19° on each side, and the predominance of soda shown by the chemical analysis indicate the probability of these being albite. The other and by far the larger set of feldspar phenocrysts consists of minute acicular crystals, which are scattered very thickly through the section where it cuts the middle of the dike, but become less numerous toward the sides. These minute crystals seem to be simple (not twinned) and are referred to anorthoclase, on account of the chemical analysis. They show a tendency toward prolongation of the corners, producing forms not unlike those of orthoclase described by J. P. Iddings* from the rhyolite of Pinto Peak, in the Eureka district, Nevada, in which the extensions do not diverge.

The relations of the two sets of feldspar phenocrysts seem to indicate that the groups of relatively large crystals (albite) are older than the others. The albite areas also show a few inclusions and some alteration.

The ferro-magnesian minerals are conspicuous by their absence from the thin sections studied, but the areas of secondary calcite and chlorite for the most part have definite outlines which strongly suggest the original presence of phenocrysts of pyroxene (augite) in the rock. In some instances these areas are partly penetrated by the acicular crystals of feldspar, somewhat after the manner of diabase augite and feldspar.

The base or groundmass is cryptocrystalline and is made up for the most part of crystals like the smaller feldspar phenocrysts. Sphærocrystalline structure was observed in some places. Some areas are not resolved by a No. 7 Fuess objective, but may be devitrified glass, as they affect polarized light.

Chemistry.—A chemical analysis of this peculiar dike was very kindly made for the writer by Dr. H. S. Washington with

* Hague, Geology of the Eureka District, U. S. G. S., Mon xx, p. 378, pl. iii, fig. 14, 1892.

the results given in column A. Column B gives an analysis of New Haven (West Rock) diabase by G. W. Hawes,* introduced for the sake of comparison as illustrating the normal diabase. The analysis given in column A was made on mate-

	A		B
SiO_2	60·13		51·78
TiO_2	tr.		1·41
Al_2O_3	20·47		12·79
Fe_2O_3	1·04		3·59
FeO	0·72		8·25
MnO	tr.		0·44
MgO	1·15		7·63
CaO	2·59		10·70
Na_2O	9 60		2·14
K_2O	1·06		0·39
Ign. (CO_2 and H_2O)	3·44	H_2O	0·63
		P_2O_5	0·14
	100·20		99·89

rial dried at 110° C. The specific gravity of the rock at 11° C. was 2·63 (Washington). Since the powdered rock effervesces rather strongly on the addition of cold HCl and considerable calcite is seen under the microscope, the loss on ignition must be largely CO_2.

This composition indicates that the rock belongs to the group of keratophyres (or possibly the bostonites of Rosenbusch), though the percentage of Al_2O_3 is rather high and the soda predominates over the potash to a greater degree than usual. About 87 per cent of the rock is feldspar and it would all seem to be anorthoclase, with the exception of the albite phenocrysts. The rock shows more CaO and MgO than the keratophyres quoted by Zirkel in his "Lehrbuch der Petrographie," but the excess of the former may be accounted for by the amount of secondary calcite present in it.

One of the striking features of the Triassic igneous rocks of the Atlantic border from Nova Scotia to North Carolina is their uniformity in appearance and in mineralogical and chemical composition. Particular emphasis has been put upon this feature by J. D. Dana† and it has been referred to by many of the writers on these Triassic areas. In his treatise on "The Newark System," I. C. Russell‡ has noted this uniformity in

* This Journal, III, ix, 186, 1875, and U. S. Nat. Mus. Proc., vol. iv, p. 132, [1881] 1882.

† This Journal, III, vi, 104–115. Also in his Manual of Geology and elsewhere.

‡ Bull. U. S. Geol. Survey, No. 85, pp. 67, 68, 1892.

these igneous rocks and has given a complete series of references to papers dealing with their mineralogical and their chemical composition, to which the reader is referred for any further details. H. D. Campbell and W. G. Brown,* however, describe petrographically and give the chemical analyses of two trap rocks from the Triassic of Culpeper county, Virginia, which depart from the "normal diabase" of Hawes and other observers. One of these is a hypersthene-diabase and the other an olivine-hypersthene-diabase. Another departure from the monotonous trap has been reported by L. S. Griswold,† who describes a very basic dike consisting essentially of augite, hornblende and biotite, with almost no feldspar, from Beseck Lake, near Baileyville, Conn., but gives no chemical analysis of the rock. The three instances of variation just cited are all of rocks as basic as or more basic than the normal or average diabase of the Triassic areas mentioned. The dike described in the present paper is the first one to be recorded from these areas in which the rock is acid or relatively acid.

* Bull. Geol. Soc. Amer., ii, 339–347, 1891.
† Bull Mus. Comp. Zool., xvi, 239–242, 1893.

Am. Mus. Nat. Hist, New York, Feb., 1897.

ART. XXVII.—*The Application of Iodic Acid to the Analysis of Iodides;* by F. A. GOOCH and C. F. WALKER.

[Contributions from the Kent Chemical Laboratory of Yale University.—LXIII.]

IT has long been understood that iodic acid is easily and completely reduced by an excess of hydriodic acid with the liberation of iodine according to the equation:

$$HIO_3 + 5HI = 6I + 3H_2O.$$

To apply this reaction to the quantitative estimation of iodic acid, it is only necessary to add to the free iodic acid or soluble iodate an excess of a soluble iodide, to acidify—best with dilute sulphuric acid—and to titrate the iodine thus set free with sodium thiosulphate, one-sixth of the iodine found being credited to the iodic acid.

It has been shown recently by Riegler* that this reaction may be also applied to the quantitative estimation of iodides, the iodine set free upon the addition of a known excess of iodic acid to the iodide solution being removed by petroleum ether, and the residual iodic acid titrated directly with sodium thiosulphate.

The present investigation was undertaken to define more particularly the limit of applicability of the reaction and to establish, if possible, a direct method for the quantitative estimation of iodides, dependent upon the action of iodic acid or an iodate in the presence of free sulphuric acid, neutralization of the solution by means of an acid carbonate, and titration of the free iodine by arsenious acid—five-sixths of the iodine thus found being credited to the iodide to be estimated. It has been found that by fulfilling certain necessary conditions, the proposed method is entirely successful, so far as concerns the estimation of iodine in iodide solutions free from large amounts of chlorides as bromides.

In a system containing a considerable quantity of free iodine with variable amounts of the other reagents mentioned, as well as possible impurities, it is conceivable that secondary reactions may occur, depending largely on conditions of mass, time and temperature, and of a sort likely to alter the amount of recoverable iodine, or to exert an excessive oxidizing influence on the arsenious acid finally titrated. It has been established by Schönbein, Lunge and Schoch, and others, that iodine forms compounds with the alkalies of the type R–O–I, and Phelps† has recently found that the formation of some such com-

* Zeitschr. für Anal. Chem., xxxv, 305. † This Journal, ii, 70, 1896.

pound, accompanying the iodate naturally expected, is distinctly recognizable when iodine and barium hydroxide interact at ordinary temperatures. It has been shown, also, in a former paper from this laboratory* that free iodine or an iodide interacts very easily with iodic acid in the presence of dilute hydrochloric acid with the formation of iodine monochloride, according to the equations:

$$HIO_3 + 2I_2 + 5HCl = 3H_2O + 5ICl.$$
$$HIO_3 + 2KI + 5HCl = 3H_2O + 2KCl + 3ICl$$

Moreover, organic compounds containing the groups $-I=O$ and $-I\overset{=O}{\underset{=O}{}}$, in which iodine seems to be analogous to nitrogen, result in great variety from the oxidation of halogen substitution products. It would seem, therefore, that the formation of inorganic reduction products of iodic acid under the conditions likely to obtain in this analytical process might be by no means beyond the bounds of possibility.

A few simple qualitative tests to determine the possibility of interaction between small quantities of iodine and iodic acid alone met with negative results. Thus, a single drop of a decinormal solution of iodine, made as usual in potassium iodide, gave when added to 10^{cm^3} of decinormal iodic acid a distinctive color to chloroform. Similar results were obtained when the iodine was employed in aqueous solution in which there was no alkaline iodide. A few drops of an aqueous solution of iodine treated (in either order) with 10^{cm^3} of a saturated solution of potassium bicarbonate and 10^{cm^3} of decinormal iodic acid gave the same distinctive color to chloroform as came from the same amount of iodine in the absence of the iodic acid. So it appears that if in the system under consideration, reactions do occur between iodic acid and iodine to alter the amount of iodine recoverable, such action is not appreciable between small amounts of these materials. This, however, does not preclude the possibility of perceptible changes under the mass-action of a large amount of iodine.

The reactions of hydrochloric acid, and probably of hydrobromic acid, in the presence of varying amounts of iodic acid, iodine and iodide, as well as the reaction of the alkaline carbonate upon such mixtures are doubtless complex, more or less reversible, and dependent upon proportions and dilution. The tendency of the former reactions is toward the reduction of the molecule of iodic acid, and the formation of the chloride or bromide of iodine. Thus, Miss Roberts† demonstrated that a

* Roberts, this Journal, xlviii, 157. † Loc. cit.

solution of hydrochloric acid, so dilute that by itself it is without effect on iodic acid, acts upon a mixture of iodic acid with either free iodine or an iodide to form iodine monochloride. The action of the acid carbonate upon the iodine chloride or bromide may produce a salt of the oxy-acids and free iodine.

The practical effects, under the conditions of analysis, of the reaction between iodine, iodic acid and the halogen acids in presence of sulphuric acid, and of reactions which may occur upon neutralization by an acid carbonate, were studied in detail in a number of experiments.

TABLE I.

Effect of the Carbonate.

[5^{cm^3} H_2SO_4 (1 : 3). Total volume of liquid, 250^{cm^3}.]

	I (in KI) taken. grm.	$KHCO_3$ in excess. cm^3.	I found. grm.	Error. grm.
(1)	0·0713	very small	0·0707	0·0006 —
(2)	0·0715	very small	0·0710	0·0005 —
(3)	0·0713	10	0·0710	0·0003 —
(4)	0·0710	10	0·0706	0·0004 —
(5)	0·0723	10	0·0717	0·0006 —
(6)	0·0713	20	0·0709	0·0004 —
(7)	0·0713	20	0·0709	0·0004 —
(8)	0·3565	very small	0·3560	0·0005 —
(9)	0·3568	very small	0·3561	0·0007 —
(10)	0·3567	10	0·3563	0·0004 —
(11)	0·3596	10	0·3588	0·0008 —
(12)	0·3565	10	0·3665	0·0000
(13)	0·3572	20	0·3560	0·0012 —
(14)	0·3567	20	0·3569	0·0002 +

The preliminary experiments of Table I were made to bring out the effect of neutralizing with the acid carbonate and subsequently titrating with an alkaline arsenite a solution containing sulphuric acid and a considerable amount of free iodine. The danger of mechanical loss of iodine during the effervescence accompanying neutralization, as well as by spontaneous volatilization from the surface during the process of titration, was minimized by effecting the neutralization in the trapped Drexel washing-bottle to be described later, and making the titration in the same tall washing cylinder without transfer. To varying amounts of a recently standardized decinormal solution of iodine were added successively 5^{cm^3} of dilute sulphuric acid and varying amounts of potassium bicarbonate in excess of that necessary to neutralize the free acid, decinormal arsenious acid in slight excess of the iodine, 5^{cm^3} of starch emulsion, and decinormal iodine to coloration, the total volume of the liquid

being not greater than 250$^{cm^3}$. The results show plainly that while the loss, mechanical or otherwise, in the treatment of reasonably large amounts of fairly concentrated iodine is perceptible, it is still well within permissible limits (amounting to a little less than 0·0005 grm. in the mean), and obviously independent of the excess of the carbonate in the solution, and of the amount of free iodine present.

In the experiments of Table II the proposed process of analysis was tested upon potassium iodide taken by itself in varying amounts of a $\frac{1}{40}$ normal solution and carefully standardized by the method formerly elaborated in this laboratory.* The apparatus employed was a Drexel washing-bottle of 500$^{cm^3}$ or 1000$^{cm^3}$ capacity, according to requirements, with stop-cock and thistle-tube fused to the inlet tube and a Will and Varrentrapp absorption trap sealed to the outlet, as shown in the accompanying figure. The iodide for the test was drawn from a burette into the bottle and carefully washed down, and potassium iodate in excess of the amount theoretically necessary (namely, 5$^{cm^3}$ of a 0·5 per cent solution for every portion of 20$^{cm^3}$ of the iodide solution), was added and the volume of the liquid was adjusted to the volume at which it was desired that the iodic and hydriodic acids should react. The stopper with the thistle-tube and trap was now placed on the bottle and the trap was half filled by means of a pipette with a 5 per cent solution of potassium iodide. Five centimeters of dilute (1:3) sulphuric acid were added through the thistle-tube and washed down; the stop-cock was closed, and the solution gently agitated, if necessary, to insure a complete separation of iodine. Potassium bicarbonate in saturated solution to an amount about 10^{cm} in excess of that required to neutralize 5$^{cm^3}$ of dilute (1:3) sulphuric acid, was poured into the thistle-tube, and allowed to flow into the bottle slowly enough to avoid a too violent evolution of gas. The stop-cock was closed and the solution agitated by giving to the bottle a rotary motion, at the same time keeping the bottom pressed down upon the work-table, to prevent a possible splashing of the iodide out of the trap into the yet acid solution. When the neutralization of the solution had been completed, the bottle was shaken until the last trace of violet vapor was absorbed in the liquid. The greater part of the solution in the trap was then run back into the bottle, the stopper removed, and the tube and trap carefully washed, the washings being added to the bulk of the solution. Deci-

* Gooch and Browning: This Journal, xxxix, 188.

normal arsenious acid was introduced from a burette to the bleaching point, 5$^{cm^3}$ of starch emulsion were added, and the solution was titrated back with decinormal iodine (usually only a few drops) to coloration.

TABLE II.

Effect of Dilution.

	KI taken. grm.	KI found. grm.	Error. grm.	Approximate volume upon addition of H_2SO_4. cm^3	Volume H_2SO_4 (1:3) used. cm^3
(1)	0·0772	0·0768	0·0004 —	150	5
(2)	0·0772	0·0765	0·0007 —	"	"
(3)	0·1544	0·1546	0·0002 +	"	"
(4)	0·1544	0·1541	0·0003 —	"	"
(5)	0·3087	0·3090	0·0003 +	"	"
(6)	0·3087	0·3088	0·0001 +	"	"
(7)	0·3859	0·3864	0·0005 +	"	"
(8)	0·3859	0·3860	0·0001 +	"	"
(9)	0·0772	0·0754	0·0018 —	300	5
(10)	0·0772	0·0757	0·0015 —	"	"
(11)	0·1543	0·1532	0·0011 —	"	"
(12)	0·1544	0·1524	0·0020 —	"	"
(13)	0·0772	0·0744	0·0028 —	500	5
(14)	0·0772	0·0737	0·0035 —	"	"
(15)	0·1544	0·1521	0·0023 —	"	"
(16)	0·1544	0·1512	0·0032 —	"	"
(17)	0·3859	0·3827	0·0032 —	"	"
(18)	0·3859	0·3831	0·0028 —	"	"
(19)	0·0772	0·0744	0·0028 —	500	10
(20)	0·0772	0·0757	0·0015 —	"	"
(21)	0·3859	0·3828	0·0031 —	"	"
(22)	0·3859	0·3827	0·0032 —	"	"

Blank tests made upon a solution obtained by mixing the maximum amount of the iodate with 5$^{cm^3}$ of dilute sulphuric acid (1:3), neutralizing as usual with potassium bicarbonate, adding the iodide from the trap and 5$^{cm^3}$ of starch emulsion, showed that a single drop of iodine was invariably sufficient to bring out the starch blue. Occasionally it was found that the mixture, particularly when chlorides or bromides were present, of itself developed a trace of color, but by no means a reading tint. A correction of the one drop of iodine necessary to bring out the color reaction in the blanks, was applied uniformly in the analytical process.

The number of centimeters of decinormal arsenious acid required to bleach the free iodine, multiplied by 0·01383 (log. 2·140822) gives the number of grams of potassium iodide taken for analysis, being equivalent to five-sixths of the iodine liberated in the solution.

From these results it appears that the degree of dilution of the solution at the time when the mixed iodide and iodate are acidified has an important influence on the completeness of the reaction. Thus, the mean error of the determinations in which the volume at the time of the reaction did not exceed 150$^{cm^3}$ was practically nothing, while the errors at volumes of 300$^{cm^3}$ and 500$^{cm^3}$ amounted to 0·0016 grm. and 0·0028 grm. respectively. It is obvious that the doubling of the amount of sulphuric acid used in acidifying does not increase the amount of iodine liberated at the highest dilution. The plain inference is that the interaction between the iodide and iodate should be brought about in a volume of liquid not much exceeding 150$^{cm^3}$.

In the following series of experiments, recorded in Table III, the effect of the introduction of a chloride or bromide into the iodide (before the iodate is added) was studied. The volume of the liquid at the time of acidifying was fixed at 150$^{cm^3}$, approximately, and 5$^{cm^3}$ of the dilute sulphuric acid (1:3) were used. The mode of procedure was otherwise similar to that of the foregoing series.

TABLE III.

Effect of Chloride and Bromide.

	KI taken. grm.	KI found. grm.	Error. grm.	NaCl taken. grm.	KBr taken. grm.
(1)	0·0772	0·0795	0·0023+	0·2	--
(2)	0·0772	0·0784	0·0012+	0·2	--
(3)	0·0771	0·0823	0·0052+	0·5	--
(4)	0·0773	0·0819	0·0046+	0·5	--
(5)	0·1544	0·1588	0·0044+	0·5	--
(6)	0·1544	0·1590	0·0046+	0·5	--
(7)	0·0772	0·0802	0·0030+	--	0·2
(8)	0·0773	0·0853	0·0080+	--	0·2
(9)	0·0772	0·0873	0·0101+	--	0·5
(10)	0·0772	0·0861	0·0089+	--	0·5
(11)	0·1544	0·1646	0·0102+	--	0·5
(12)	0·1543	0·1626	0·0083+	--	0·5

The influence of sodium chloride and potassium bromide in increasing the amount of iodine liberated is plain. The increase comes without doubt from the iodate, and is doubtless due to the formation of iodine chloride or bromide, during the

acidifying, by the interaction of the free iodine, the iodic acid, and the hydrochloric or hydrobromic acid, according to the reactions previously discussed. It is plain, therefore, that the value of the process in the determination of iodine in an iodide is restricted of necessity to those cases in which it is known that chlorides or bromides are not present to any considerable extent. For determining the standard of a solution of nearly pure potassium iodide, employed in so many laboratory processes, it should find useful application.

TABLE IV.

Analysis of Pure Potassium Iodide.

	KI taken. grm.	KI found grm.	Error. grm.
(1)	0·0814	0·0816	0·0002 +
(2)	0·0814	0·0813	0·0001 —
(3)	0·0814	0·0805	0 0009 —
(4)	0·0815	0·0809	0·0006 —
(5)	0·0814	0·0808	0·0006 —
(6)	0·0814	0·0806	0·0008 —
(7)	0·0814	0·0812	0·0002 —
(8)	0·1628	0·1624	0·0004 —
(9)	0·1628	0·1617	0·0011 —
(10)	0·1628	0·1621	0·0007 —
(11)	0·1628	0·1619	0·0009 —
(12)	0·1628	0·1624	0·0004 —
(13)	0·1628	0·1621	0·0007 —
(14)	0·1628	0·1626	0·0002 —
(15)	0·2442	0·2451	0·0009 +
(16)	0·2442	0·2442	0·0000
(17)	0·2442	0·2439	0·0003 —
(18)	0·3256	0·3258	0·0002 +
(19)	0·3256	0·3256	0·0000
(20)	0·3256	0·3258	0·0002 +
(21)	0·3256	0·3272	0·0016 +
(22)	0·3256	0·3256	0·0000
(23)	0·4071	0·4076	0·0005 +
(24)	0·4071	0·4080	0·0009 +
(25)	0·4071	0·4073	0·0002 +

In Table IV are comprised a number of experiments made exactly like those which seemed to give the best results in the series of Table II. The iodide and an excess of iodate (5^{cm^3} of the 0·5 per cent solution to every 20^{cm^3} of $\frac{N}{40}$ iodide) were made to interact in a volume of about 150^{cm^3}, 5^{cm^3} of sulphuric acid (1 : 3), were used to bring about the reaction, 10^{cm^3} of potassium bicarbonate were added after the neutralization of the sulphu-

ric acid was complete, and the free iodine was estimated by titrating decinormal arsenious acid, the manipulation being like that previously described in detail.

The average result of a series of several determinations in which a great excess (0·1 grm.) of potassium iodate was used, proved to be practically identical with that of a similar series in which only a small excess of the iodate was employed, so that it appears to be unnecessary in any practical work to restrict the amount of iodate below the amount necessary to decompose the maximum quantity of potassium iodide which we have handled, namely, 0·4 grm.

It appears that for the estimation of iodine in a soluble iodide free from notable amounts of chlorides or bromides, this method, depending as it does upon a single standard solution, is simple, fairly accurate, and rapid.

Art. XXVIII.—*The Granitic Rocks of the Pyramid Peak District, Sierra Nevada, California;* by Waldemar Lindgren.

[Published by permission of the Director of the U. S. Geological Survey.]

It has long been known that the summit region of the Sierra Nevada is occupied by an enormous mass of granitic rocks, and that a large part of it consists of granodiorite, a rock intermediate between a granite and a diorite, but no detailed maps have thus far been made of the granitic areas. An opportunity was offered for the study of these granitic rocks during the survey of Pyramid Peak atlas sheet, which was undertaken in the summer of 1894 by the writer, assisted by Mr. H. C. Hoover. The results are shown in the accompanying map (p. 302), compiled from the Pyramid Peak folio now in press.

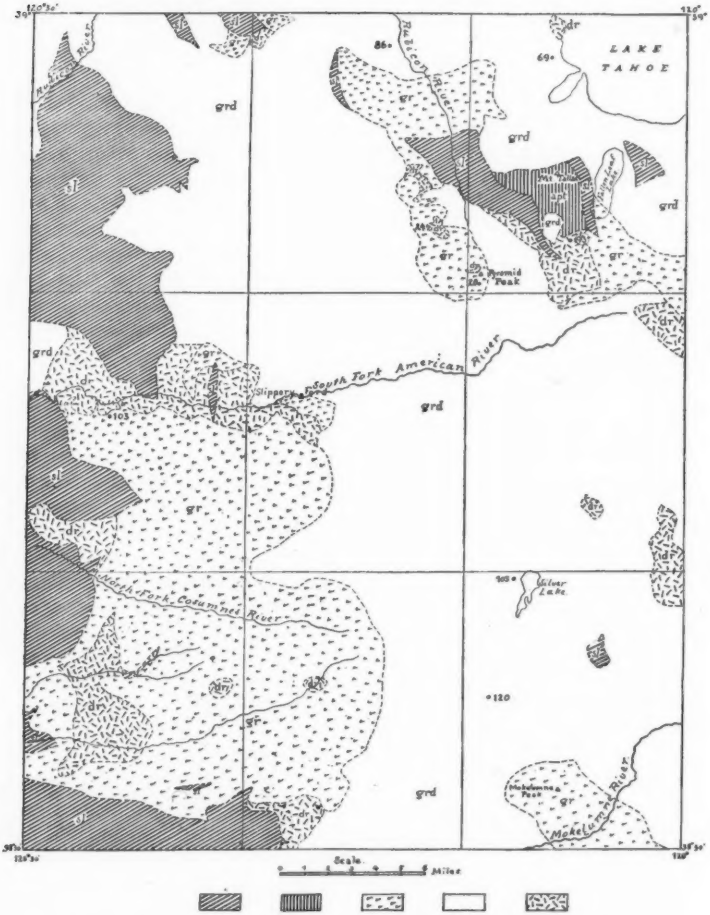
The region embraces half a degree of latitude by half a degree of longitude, and contains 927 square miles. The southern end of Lake Tahoe falls within the northern corner, and the main divide of the mountain range runs near the eastern boundary of the sheet. While the western part is occupied by an approximate plateau deeply trenched by canyons and gulches, the crest of the Sierra Nevada rises in the eastern part to lofty snow-capped mountains. The drainage of the western part is toward the Sacramento and San Joaquin rivers, while the drainage toward Lake Tahoe eventually finds its way to the deserts of the Great Basin.

The older bed-rock series consists of slates, schists and granitic rocks. These are extensively covered by Tertiary eruptives, andesite, rhyolite and basalt, which have not been indicated in the map accompanying this paper. To the west the slates, schists and accompanying basic eruptive rocks continue down to the foothills of the range and contain several small masses of granitic rocks. Toward the east the latter continue over to the eastern escarpment of the Sierra Nevada. The range in this vicinity contains two summit-ridges. The westerly, dividing the Pacific from the Great Basin, is found on this sheet, while the easterly summit divides the drainage flowing into Lake Tahoe from that running into the Carson River.

The Sedimentary Areas.

No fossils have been found in any of the sedimentary rocks of the bed-rock series within the limit of this sheet, and the age assigned is in all cases tentative only. The determinations are, however, based upon a comparison with formations of

approximately known age in adjoining areas, and they therefore possess a strong degree of probability.



A, Sedimentary slates and schists. B, Augite porphyrite. C, Granitite. D, Granodiorite. E, Diorite and Gabbro.

Under the name of the Calaveras formation the beds of Paleozoic age have been comprised which cannot at present be further subdivided. The larger part of them probably belong to the lower or middle Carboniferous. To this formation all of the sedimentary rocks along the western boundary of the

sheet belong. The sedimentary rocks are separated from the granite by an extremely irregular contact line. The bays of granitic rocks reach far into the schists and slates, and all along this contact the sedimentary rocks have been subjected to an intense contact metamorphism, but of fusion or absorption there is absolutely no evidence.

The whole of the Calaveras formation on the eastern part of the Placerville sheet and on this sheet has a pronounced siliceous character; it consists of altered sandstones, grading into quartzite, and clay slates grading into micaceous schists. The cause of the metamorphism is partly of a regional character and caused by dynamic movements affecting a large part of the Sierra Nevada, chiefly prior to the great granitic intrusions, partly of a local character, and caused by the heat and the emanations from the intrusion of enormous massses of granitic magmas. While the latter metamorphism is superimposed upon the former, and the phenomena resulting from each not always easy to discriminate, it is clearly seen that the extremely altered sediments are found only at the contacts with the granitic rocks, and that the degree of metamorphism gradually decreases away from it. The contact zones are here very wide, typical contact metamorphic rocks often being found two miles from the contacts, or even more in case of projecting masses of sedimentary rocks surrounded on all sides by granite. It does not appear probable that any of these rocks are old, pre-Carboniferous or Archean schists.

Less altered rocks, the clastic character of which is clearly apparent, occur at a few places near the western border of the sheet. They are principally dark clay-slates and quartzitic rocks, which under the microscope show their fragmental origin. Thus on Silver Creek, near the western boundary of the sheet, on Sly Park Creek, at Fort Grizzly and southeast of Tar's Sawmill. But the larger part of the Calaveras formation in this sheet is occupied by the contact metamorphic schists. In places especially exposed to the action of the granitic magma, the rock is converted to normal, medium-grained gneiss or mica-schist, and at these places the contacts with the granite, usually sharp, are liable to become indistinct. Somewhat farther away the schists are finer-grained, generally of a brownish color, from the biotite contained, or of a silvery lustre caused by scales of muscovite on the planes of schistosity. The surface is frequently knotty, changing to normal "Knotenschiefer." They often carry andalusite, characteristic for contact rocks, in well-developed crystals, and such rocks may be found more than one mile distant from the contact.

Excellent exposures are found in the deep canyons of Silver Creek, Camp Creek and the north fork of the Cosumnes,

but they are accessible only with difficulty. The schistosity is indicated on the outcrop by lines, straight on the whole, but delicately wavy in detail; heavy benches alternate with streaks, in which the lamination is very fine. Nodules and nests of apparently segregated quartz are common. On the ridges and slopes satisfactory outcrops are rarely seen, as the rock here weathers to a dark-red soil.

A part of the area in the southwestern corner, is also intensely altered; micaceous schists and a striped green and white schist, consisting of pyroxene, quartz, feldspar and wollastonite, evidently a product of contact metamorphic action on limestone, appear in this vicinity.

The stratification can only rarely be observed beyond doubt, as for instance where quartzite and black clay-slate alternate, but it is probable that in most cases the stratification approximately coincides with the superimposed schistosity. In the northern area the strike of the schistosity is generally due north and the dip either about vertical or westward at a steep angle, this being contrary to the general rule further down the slope. South of the south fork of the American River the strike is more irregular, but generally east-west, while the dip is always within 20° of the perpendicular and usually to the north. Comparing with the S.E. part of Placerville sheet and the N.E. part of Jackson sheet, it will be seen that the series in these regions also has an abnormal east-west strike; the cause may possibly be sought in the mechanics of the intrusion, the slates in this vicinity being especially torn up by deeply incised bays of granitic rock. Horizontal and inclined joints also traverse the schists, separating them into rhomboidal fragments. The contact of the schists with the granitic rock is usually best defined where that line runs parallel to the schistosity. Wherever the contact cuts across the strike a stronger metamorphism, accompanied by a feathering out of the schists and by an injection of granitic magma, is often noted. The cleavage of the schists has not been produced by the pressure of the intruding magma; it existed before the granitic irruption.

A few isolated areas of schists, quartzites and highly-altered tuffs referred to the Jura-trias are scattered on both sides of the crest in the northern part of the area of the Pyramid Peak sheet. One of the principal reasons for assigning them, with doubt, however, to the Jura-trias is their position in the continuation of strata known to be of that age in the area of the Truckee sheet adjoining northward; another is that the principal mass, near Mount Tallac, is intimately connected with large masses of dark-green diabase-porphyrite and porphyrite tuff, which is characteristic of the Jura-trias at Sailor Canyon (Colfax sheet) and northward. The color of the outcrops of

these schist areas is usually reddish brown, contrasting strongly with the light-gray granodiorite.

The two small areas at the northern boundary consist of quartzite and black slate, the latter altered near the contacts to gneissoid micaceous schist; the contacts are usually sharp, extremely so where the road crosses the western area. At other places, as for instance, on the west side of Loon Lake, the contact is very unsatisfactory, the reddish granitic outcrops being everywhere mixed with schistose fragments.

The long and narrow area west of Tells Peak is strongly metamorphosed and composed of gneissoid schists, quartzites and mica-chlorite-andalusite schists.

The largest area of supposed Jura-trias lies in Rockbound Valley between Mount Tallac and the Pyramid Peak Range; it has a roughly triangular form and is distinguished by outcrops of dull gray or brown color. The rocks consist of a series of clearly stratified black slates and white quartzitic rocks; beautifully banded hard rocks, dark-gray and white, also occcur in Rockbound Valley. The normal strike appears to be N.N.W., with a dip of about 45° to the east; the schistosity is not prominent. In the western point of the area the rocks are disturbed and dip in different directions. In the vicinity of Suzy Lake white quartzitic rocks crop, less clearly stratified, often indeed appearing massive. The microscope shows that the banded rocks from Rockbound Valley and in the Suzy Lake region are porphyrite tuffs, probably deposited contemporaneously with the eruption of the large porphyrite mass of Mount Tallac. Dikes of typical diabase porphyrite were noted on the west shore of Suzy Lake; on the western slope of Rockbound Valley uralite-porphyrites appear which would seem to lie conformably in the sedimentary series and are made somewhat schistose by pressure.

The Granitic Rocks.

The granitic rocks exhibit a rather unexpected variety in composition and structure. They include granites, aplites, granodiorites, diorites, and gabbro, by far the largest areas being, however, occupied by the granodiorite. The structure is always massive, a well defined schistosity being nowhere observed. Joints are frequent, however, and near the summit the rocks are intersected by extensive fissure systems.

Granite.—A normal biotite-granite or granitite occupies several large areas along the Pyramid Peak Range at Echo Lake, at Mokelumne Peak, and about the headwaters of the Cosumnes River. Its outcrops are generally distinguished by a light-yellowish or reddish color, due to the sesquioxide of iron contained in the orthoclase. It is harder and of a firmer texture

than the granodiorite, and its areas include the highest and roughest ridges in the region. For the same reason bowlders and cobbles of granitite are much more abundant than those of granodiorite. While it varies somewhat in appearance and constitution, yet it is a typical granite. The rock is coarse-grained and has often a decided tendency towards a rough porphyritic structure. The orthoclase appears as large grains and imperfect prisms of reddish gray color up to two or even three centimeters long; the quartz is very prominent in dark-gray rounded grains up to one centimeter in diameter, while the black mica and smaller quartz and feldspar grains lie between these larger constituents. Hornblende occurs only rarely; when it appears plagioclase usually also enters into the composition, and transition-forms to granodiorite result.

TABLE OF ANALYSES OF GRANITIC ROCKS.

Analyst: Mr. Geo. Steiger.

	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2	77·68	72·95	67·45	68·13	67·14	68·32	65·88	51·47	57·11
TiO_2	·14		·58						
Al_2O_3	11·81		15·51						
Fe_2O_3	·72		1·76						
FeO	·51		2·21						
MnO	trace								
CaO	·72	1·16	3·60	3·51	4·07	3·21	4·11	10·18	5·32
MgO	·18		1·10						
K_2O	5·00	5·43	3·66	3·58	2·70	3·37	2·88	1·08	4·11
Na_2O	2·96	3·74	3·47	3·13	3·09	2·51	2·41	2·86	3·06
Water 100—	·04		·14						
Water 100+	·27		·63						
P_2O_5	·10		·12						
	100·13		100·25						

I. 164 Pyramid Peak collection; granitite: Placerville Ditch, ⅓ mile north of Ditch-camp 7. Lat. 38° 45·5′; Long. 120° 36·1′.

II. 20 Pyramid Peak collection; granitite; south side Pyramid Peak, 1,200 feet below summit. Lat. 38° 50·2′; Long. 120° 9·5′.

III. 103 Pyramid Peak collection; granodiorite; road, ¼ mile west of Silver Lake House. Lat. 38° 39·8′; Long. 120° 7·7′.

IV. 69 Pyramid Peak collection; granodiorite; trail Emerald Bay to Rubicon Point, 1½ mile south of latter. Lat. 38° 48·6′; Long. 120° 6·3′.

V. 86 Pyramid Peak collection: granodiorite; 1 mile E.S.E. of Rockbound Lake. Lat. 38° 58·8′; Long. 120° 13·7′.

VI. 120 Pyramid Peak collection; granodiorite; Big Mud Lake bears N. 30° W. and is 1½ mile distant. Lat. 38° 35·6′; Long. 120° 9′.

VII. 177 Pyramid Peak collection; granodiorite; Meek's Creek, 2 miles up from mouth at Lake Tahoe. Lat. 39° 0·8′; Long. 120° 9′.

VIII. 24 Pyramid Peak collection; diorite; Pyramid Peak bears S. 50° E. and is 3 miles distant. Head of Blakeley Creek. Lat. 38° 52·3′; Long. 120° 12′.

IX. 93 Pyramid Peak collection; Glen Alpine Spring bear N. 40° W. and is ¾ mile distant. Lat. 38° 51·9′; Long. 120° 5·2′.

Under I in the table of analyses is given one of these granites of an unusually fresh type. It is a light-gray, hard, granular rock with an approximation to a porphyritic habit. Macroscopically are noted large quartz grains up to five millimeters in diameter, large grains and imperfect prisms of feldspar up to ten milimeters in length. Between these larger grains lie the remaining feldspar-quartz mass with somewhat finer grain. Biotite in foils up to three millimeters in diameter are scattered through the rock. Microscopically, the structure is almost allotriomorphic, the rock being principally made up of large, irregular and very interlocking grains of microcline, microperthite, and quartz. In the microline lie imbedded smaller grains and prisms of an acid plagioclase, as well as some quartz. Between the larger grains lie in places aggregates of quartz, microcline, albite, and oligoclase, also with interlocking structure. Biotite is sparingly present. The analysis may be calculated as follows:

		Per Cent.
SiO_2	18·23	
Al_2O_3	5·18	
K_2O	4·76	
$K\,Al\,Si_3O_8$		28·17
SiO_2	17·24	
Al_2O_3	4·89	
Na_2O	2·96	
$Na\,Al\,Si_3O_8$		25·09
SiO_2	1·05	
Al_2O_3	·93	
CaO	·49	
$Ca\,Al_2\,Si_2O_8$		2·47
P_2O_5	·10	
CaO	·13	
Cl	·02	
Apatite		·25

TiO_2	·14
SiO_2	·11
CaO	·10

Titanite	·35
Biotite	3·10
Magnetite	·61
Quartz	39·80
Water	·31
	100·15

From the total amount of potash 0·24 was tentatively subtracted for the biotite. The total lime, after subtraction of amount needed for titanite, was counted to $CaAl_2Si_2O_8$; the total soda as $NaAlSi_3O_8$. On basis of remaining Al_2O_3 a portion of the silica was referred to the biotite and half the amount of iron oxide and sesquioxide subtracted as magnetite.

There remains then for the biotite:

SiO_2	1·25	40·32
Al_2O_3	·81	26·13
Fe_2O_3, FeO	·62	20·00
MgO	·18	5·81
K_2O	·24	7·74
	3·10	100·00

This corresponds fairly well with a normal biotite.

A specimen from the south side of Pyramid Peak was subjected to a partial analysis (II), which shows it to be of practically the same composition as (I), though a little more of the anorthite molecule is present. The granite is on the whole very constant in mineral composition and it is believed that these analyses well indicate its average composition.

*Granodiorite.**—As mentioned before, the granodiorite is the prevailing rock, occupying a broad belt extending across the whole area from north to south. It is of a crumbling nature, falling an easy prey to the destructive forces of weathering and

* The name of granodiorite was first proposed by Messrs. G. F. Becker, H. W. Turner and W. Lindgren in 1892. References to the rock may be found in the following places:

Geologic Atlas of the U. S., Folios 3, 5, 11, 18, 29.

W. Lindgren: The Auriferous Veins of Meadow Lake, this Journal, III, vol. xlvi, p. 201, 1893; U. S. Geol. Survey, 14th Ann. Rep., pt. 2, p. 243; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 35.

H. W. Turner: U. S. Geol. Survey, 14th Ann. Rept., p. 478; U. S. Geol. Survey, 17th Ann. Rept., pt. 1, p. 724.

erosion. The outcrops are of rounded form, often weathering into huge detached boulders; the color is very light gray. The granodiorite is a medium to coarse-grained rock, the average diameter of the grain being 2 to 3 millimeters. The grayish quartz and white feldspar grains are of about equal size. The quartz is decidedly less prominent than in the granite, and the feldspar does not reach the dimensions attained in the latter rock. Black mica and hornblende are usually present in about equal quantities. The foils of the former reach 2 or 3 millimeters in diameter, while the hornblende is roughly prismatic, the crystals sometimes attaining 1 centimeter in length. By reason of this development of the hornblende, a somewhat porphyritic aspect may occasionally be obtained. Titanite is nearly always present in small isolated brownish grains. A little magnetite is also a constant accessory mineral. The appearance and composition of the rock is very constant over large areas, with only small variations in grain and in the quantity of hornblende and biotite. In a few places the quantity of hornblende diminishes and the rock then assumes a habit more similar to that of granite; thus, for instance, at Buck Island Lake, between Rubicon Peak and Rubicon Point and in the area east of Fallen Leaf Lake. Microscopical and chemical investigation shows the rock at this point to be a granodiorite, though rather rich in orthoclase.

Analysis III shows the composition of a typical granodiorite from the northwestern shore of Silver Lake. It is a light-gray granular rock composed of white or yellowish feldspar in grains and imperfect prisms, grayish quartz, biotite foils up to 1 millimeter in diameter, and a rather abundant dark-green hornblende in well-defined stout prisms up to 8 millimeters in length. Grains of brown titanite are also present.

The microscrope shows the structure typical for granodiorites: Very plentiful, roughly idiomorphic prismatic crystals of an acid plagioclase, sharply outlined foils of yellowish brown biotite partly decomposed into chlorite, and grains of imperfect prisms of ordinary brownish green hornblende, accompanied by a few grains of magnetite. These constituents are cemented by anhedral quartz, orthoclase, and a little microline. Titanite occurs in small grains enclosed in biotite. On the borders of the plagioclase and orthoclase a little micropegmatite often occurs. Some slight evidences of crushing are present in this rock, though such phenomena are in general very rare in the granodiorites.

As neither the hornblende nor the biotite has been analyzed, it is clear that no exact calculation of this analysis can be made. It is, however, possible to arrive at the approximate composition by means of the following calculation:

		Per Cent.
SiO_2	11·48	
Al_2O_3	3·27	
K_2O	3·	
$KAlSi_3O_8$		17·75
SiO_2	20·20	
Al_2O_3	5·74	
Na_2O	3·47	
$NaAlSi_3O_8$		29·41
SiO_2	5·14	
Al_2O_3	4·37	
CaO	2·40	
$CaAl_2Si_2O_8$		11·91
SiO_2	·42	
TiO_2	·58	
CaO	·40	
Titanite		1·40
P_2O_5	·12	
CaO	·16	
Cl	·02	
Apatite		·30
Magnetite		·84
Hornblende and biotite		12·79
Quartz		25·71
		100·11

For the hornblende and biotite there remains:

SiO_2	(4·50)
Al_2O_3	2·13
Fe_2O_3	1·13
FeO	2·00
CaO	·64
MgO	1·10
K_2O	·66
H_2O	·63
	12·79

The estimation is made in the following way: A small amount of potash and soda being first subtracted for the bio-

tite and hornblende, the remainder was calculated as orthoclase and albite. Further, 1·20 per cent lime was tentatively subtracted from the total as belonging to the hornblende, and 0·56 per cent for titanite and apatite, the remainder being calculated as anorthite. The amount of magnetite is estimated. From the remaining silica 4·50 per cent was subtracted to approximately correspond with the Al_2O_3, and MgO available for biotite and hornblende.

The analysis is entirely typical for granodiorite and is extremely similar to the analyses of the granodiorite from Nevada City and Grass Valley, Nevada County.*

Under No. IV a partial analysis is recorded of a rock near the shore of Lake Tahoe, not far from the northern boundary line of the sheet. The rock is coarse granular, consisting chiefly of slightly reddish feldspar with much quartz. Hornblende and biotite are present in about equal quantities, but the hornblende occurs in small grains and prisms only. It was thought that this rock presented a certain similarity to the granitite and it was therefore analyzed, but the figures obtained indicate it to be a normal granodiorite. The microscope shows a few large carlsbad twins of microcline and microperthite; an abundance of imperfect prisms of plagioclase imbedded in anhedral quartz, orthoclase, microcline and microperthite, the latter two often as Carlsbad twins; well-defined foils of biotite, a little hornblende and a few grains of titanite.

Analysis V shows the composition of a granodiorite from the valley of the Rubicon, 2 miles south of the northern boundary line of the sheet. Macroscopically the rock is very similar to IV. Under the microscope the same normal granodiorite structure is apparent. As in IV much of the potassium feldspar cementing the plagioclase prisms is microcline. The analysis indicates a normal granodiorite.

Analysis VI shows the composition of the granodiorite 6 miles south of Silver Lake in Bear River canyon. The rock is normal except for the fact that the quartz is rather prominent in grains up to 6 millimeters in diameter and that the biotite predominates over the hornblende.

Under the microscope it is evident that the cementing orthoclase and microcline are rather abundant, but the granodiorite structure is well-defined. Titanite is abundant. The analysis shows a closer approach to the granitite than in any other of the rocks here examined; this is expressed in the high percentage of silica and potash, as well as in the relatively low percentage of lime. Still there is a wide gap between this rock and a normal granitite.

Analysis VII shows the composition of the granodiorite of

* 17th Ann. Rept. U. S. Geol. Survey, pp. 38 and 42.

Meeks Creek, Truckee sheet, a few miles north of the northern boundary of the Pyramid Peak sheet. Both in appearance and composition the rock is a normal granodiorite.

Comparing the analytical and microscopical results with the field notes, it is clear that the granodiorite, as it appears in the High Sierra, is a rock of well-defined and fairly constant composition, structure, and appearance. It is neither a normal diorite, nor is it a granite; it is clearly an *intermediate* type, occupying a place between normal quartz-mica-diorite and quartz-monzonite (Brögger).* All transitions toward diorite and, more rarely, toward granitite, may be found, but they are local and do not cover large areas, while the normal granodiorite is the prevailing rock of the Sierras. Comparing the type here described with the granodiorites of the many smaller areas enclosed in the slates on the western flank of the range, it can be stated that the latter as a rule approach more closely to the quartz-diorites, the percentage of lime being higher and the percentage of potash more often smaller than equal to that of soda. A few of these smaller granitic areas could, in fact, almost as well be indicated as quartz-mica-diorites. In the general habit, however, in the percentage of quartz, hornblende, and biotite, and in the constant presence of titanite, they are entirely similar to the granodiorites of the High Sierra. Microcline, not common in the granodiorites of the foothill region, occurs abundantly in those of the High Sierra.

Diorite and gabbro.—When the amount of hornblende and biotite in a granodiorite increases, it is usual to find the quartz and orthoclase relatively diminished in quantity and rock types more closely allied to normal diorites result. At the same time pyroxene frequently appears, and transitions into gabbro are formed. These more basic rocks in places form smaller areas enclosed in granodiorite or granite; more frequently they lie between the two rocks or on the contacts between granite or granodiorite and the schists. The rock in these areas is of a very variable structure and composition, ranging from a quartz-diorite to a gabbro, almost approaching a peridotite. The latter type is, however, rare. The normal diorite, such as occurs in the canyon of the south fork of the American River, is medium to coarse-grained, composed nearly entirely of hornblende and plagioclase. A little quarz, however, very frequently enters into the composition. Typical coarse-grained gabbros with large reddish gray basic feldspars and dark green

* Though it is often difficult in practice to separate the normal quartz-mica-diorite from the granodiorite, it would seem suitable to restrict granodiorite to the following limits: SiO_2 59—69 per cent, Al_2O_3 14—17 per cent. Fe_2O_3 1½—2¼ per cent, FeO 1½—4¼ per cent, CaO 3—6½ per cent, MgO 1—2½ per cent, K_2O 1—3¾ Na_2O 2½—4½.

uralitized pyroxene occur near Round Top and to the west of Slippery Ford, and are connected with the diorites by abundant transitions.

Normal syenites have not been recognized, but intermediate rocks of the composition of monzonites may occur in places; it does not appear practicable, however, to separate them from the diorites.

A normal diorite from the western slope of the Pyramid Peak range was partially analyzed (VIII). The rock is granular, dark grayish green, the grains, averaging two millimeters in diameter, consist of feldspar, dark green hornblende and a little biotite. The plagioclase, which does not exceed andesine in basicity, occurs in imperfect short prisms, occasionally cemented by a little orthoclase. There is no quartz. The mica is in well-defined yellowish brown foils, often including small feldspar prisms. The hornblende occurs in irregular grains, but is sometime roughly idiomorphic. Small grains of titanite are present. The structure is typically hypidiomorphic. The composition is that of a normal diorite, indicated by the high percentage of lime and soda and small amount of potash. The hornblende must contain much lime.

Analysis IX shows the composition of one of the intermediate rocks, occurring in a diorite area a couple of miles south of Tallac Peak. It is a coarse-grained, dark rock made up chiefly of hornblende, a little biotite and feldspar. It carries a considerable amount of orthoclase, and its composition corresponds nearly exactly to the monzonite from Mulatto, analyzed by Lemberg.*

The relation and succession of the granitic rocks.—The contacts of the granodiorite with the granite are sometimes sharp, but more commonly much pegmatite, diorite and granite-porphyry occur on them, making them indistinct. In other places transition forms may be observed, such as at the northern end of Pyramid Peak granite area. Especially interesting are the exposures along the Pyramid Peak range. Wherever branches or bays of granodiorite reach into the granite a great variety of lighter or darker dioritic rocks make their appearance, in places bordering sharply against the granodiorite, at other times forming extremely graded transitions into it. Near the contacts of the schist areas it is quite common to find the granodiorite gradually growing darker and changing to diorites. The contacts between the granite and the diorite are usually sharper, and south of the south fork of the American River abundant well-defined dikes of granite occur in the diorite.

* W. C. Brögger: Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo in Süd Tyrol, p. 62.

There is no doubt that all of the granitic rocks are later than the altered sedimentary rocks and the augite-porphyrite, but it must be confessed that in spite of good exposures the evidence as to the relative age of the granite, granodiorite, diorite and gabbro is not decisive, and even in some respects contradictory. There is some evidence, based on the general form of the Pyramid Peak granite area and the manner in which it includes the slate fragments, as well as on the occurrence in it of dikes of a rock allied to granodiorite, tending to show that the granite was intruded earlier than the granodiorite. On the other hand, it is unquestionably true that the granite of the southwestern corner sends out numerous dikes into the diorite of the south fork of the American River; this diorite again shows numerous local transitions to apparently normal granodiorite, so that if it be conceded that this diorite area is of approximately the same age as the main granodiorite mass, it would follow that the granite would be later than the granodiorite. The probability is that the intrusion both of the granite and of the granodiorite was accompanied by minor intrusions of acid and basic magmas, and that there are diorites, pegmatites and aplites of the age of the granodiorite and of that of the granite, the latter being the older rock; only on this supposition can the contradictory testimony be explained; the diorites of the canyon of the South Fork and in the smaller areas along the western boundary would then belong to the period of granitic intrusions, while those of Round Top and the Pyramid Peak range would belong to the granodiorite.

Washington, D. C., Jan., 1897.

ART. XXIX.—*Difference in the Climate of the Greenland and American sides of Davis' and Baffin's Bay;** by RALPH S. TARR.

Route followed.—During the summer of 1896, I made the journey along the Labrador and Baffin Land coasts, northward in the latter part of July and southward in early and middle September.† The period between these times was spent on the Greenland coast, the northernmost point visited being in lat. 74° 15′. Some features concerning the marked difference in climate on the two sides of the sea separating Greenland from the American land, apparently well known to Arctic voyagers, but new to me, have seemed to warrant brief statement.

Climate of American and Greenland sides.—On the northward trip a landing was made at the island of Turnavik, about in lat. 55°, on July 20. There extensive snow banks were found to be still lingering in the sheltered valleys, at points no more than one or two hundred feet above the sea level. Indeed several hundred miles to the south, on the west coast of Newfoundland, snow was seen. Later a landing was made in southern Baffin Land, on Hudson Straits, and here snow banks were also found. Nearly the entire distance traversed by the ship, from southern Labrador to the mouth of Cumberland Sound, one or two degrees south of the Arctic Circle, where we left the American coast, we met with floe ice, often so heavy that progress through it was slow and difficult. This was an unusual season, and hence the conditions were somewhat more severe than common. The ice is rarely so abundant at this season of the year. The presence of great floes, moving southward in the Labrador current, so chilled the air that the thermometer often stood in the thirties, and frequently descended to the freezing point. On July 30 snow fell in some quantity upon the ship, which then lay off Frobisher Bay.

On July 30 an unsuccessful attempt was made to enter Cumberland Sound, which was then, as often in this season of the year, completely shut in by the heavy ice floe. Not being

* It is a rather remarkable fact that the great bay which extends north to the Arctic circle, from the main Atlantic to Davis' Straits, should have been given no name. Baffin's Bay extends from Cape York to Davis' Straits at the Arctic circle; but no name is applied to the bay south of this. Because of the difficulty experienced in the attempt to write this article, on account of the absence of such a name, I would propose for the bay between Labrador and Greenland and south of Davis' Straits, the name *Davis' Bay* after the first navigator of these waters, who, in the year 1587, made the perilous voyage in a sailing vessel as far north as Upernavik.

† As a member of the Peary Greenland Expedition.

able to penetrate the ice, the ship left this bleak coast and crossed Davis' Straits to Disco island on the Greenland coast, going north four or five degrees. There we found a decided change in climatic conditions. The air was balmy, and although the highland portions of the mainland and island were ice-capped, and snow banks were seen in the protected valleys, the season was distinctly more advanced and more pleasant than on the American side two or three hundred miles southward. The flora was richer, insects were abundant, and everything betokened summer. Passing still farther northward to the Upper Nugsuak peninsula, in lat. 74° 10′, although the climate was somewhat more severe, it was distinctly farther advanced than on the American side which had been left a few days before, and which lay five or six hundred miles to the southward.

From August 7 to September 7, although by the latter date the night had begun, with the sun setting at about 7.30 in the evening, we were able to live comfortably in lat. 74° 10′ with no other protection than that of tents. During this time the lowest recorded temperature was 28°, which came at the coldest part of the night. The storms brought rain and not snow. Returning, we left Disco on September 11 after a beautiful, warm day. Snow had recently fallen upon the uplands, but many flowers were still in blossom near sea level. Coming southwards to the mouth of Cumberland Sound, our first view of the American land showed a snow-covered surface, and from this point to the north end of Newfoundland, freshly fallen snow was seen on the land.

Although we later found that the floe ice had disappeared from the Labrador coast, it still blocked a portion of the entrance to Cumberland Sound, and for sixty hours the ship was held a prisoner in this ice before we could pass into the Sound. After entering Cumberland Sound we encountered violent snow storms, and the fall of snow was sufficient to cover the surface of the land. Hence in this latitude, in the summer of 1896, snow fell on July 30 and on some day previous to September 13, the latter fall being sufficient to whiten the hills as seen from the sea.

Influence of Ocean Currents.—The causes for this difference between the climate of the two sides of a sea separated by only a few hundred miles in the broadest portions, are perhaps several, though the chief cause is to be found in the ocean currents. The icebergs and floes of the Arctic pass southward on the American side, and the cold ice-laden waters influence the climate of the neighboring land very perceptibly. On the Greenland side there is a current in an opposite direction, hence carrying warm water northward.

It is difficult to say how far the north-moving current

extends, and also how far from the land its influence is felt. I should say that the current does not probably reach far to sea; because if it did, the bergs and winter sea ice would not readily escape, and the Greenland coast would be ice-bound in summer, rather than ice-free as we found it.* There are some reasons for thinking that the north-moving current extends as far as the northern end of Melville Bay. The fact that great quantities of ice accumulate and remain there, rendering this bay notoriously difficult to navigate, seems to show that something interferes with the southward movement of the ice.

Pointing toward the same conclusion that the warm current reaches into Melville Bay, are the observations which were made from our camp at Wilcox Head, the point of the Upper Nugsuak peninsula which projects into Baffin's Bay near the southern end of Melville Bay. During two or three weeks encampment at this exposed point, it was noticed that the ice-bergs floated almost uniformly toward the north. It is true that this was a period during which south winds prevailed, but even when these did not blow, the bergs still moved northward. Moreover with but one hundred feet, or less, above the water, it seems improbable that the great ice masses which floated past our camp could have been driven so rapidly by mere wind action, particularly when the wind was not strong.

Influence of Winds.—There are two other reasons for climatic moderation on the Greenland coast; in the first place the winds from all directions, excepting the east, reach the shore from water, the temperature of which is well above the freezing point during the summer. The entire coast of this part of Greenland is then free from floe ice, and is encumbered only with scattered bergs and berg fragments. Hence on this coast the water is warmer than that on the opposite side of Baffin's Bay. On the one shore there is a cold ice-laden current, on the other a slowly moving drift of water *toward* the north. One might expect that the wind blowing from the ice cap of Greenland, the prevailing wind while we were there, would be cold; but the reverse is true. This wind, descending from great altitudes and passing over the surface of snow and ice, is really warmer than that from the sea, and at times it was

* Incidentally I would call attention to the fact that this clearing of the various forms of ice from the Greenland coast is usually made possible by the winds that blow from the ice cap. It is an interesting coincidence that the very cause for most of the ice gives rise to conditions which permit this to be carried away. From the cold highland area of inland Greenland, the dense air settles and blows outward, producing off-shore winds, which keep the fjords free of ice encumbrances; and at times, extending out from the coast, the wind drives this ice well to sea, where it comes under the influence of the south-moving currents, which I believe must exist not far from the Greenland shore.

noticeably warm, rapidly descending air. The explanation is no doubt the same as the explanation of the chinook and foehn winds.

Cause of difference in Glaciation.—On the Greenland side the land is mainly submerged beneath the great ice cap, with branches extending to the sea through the valleys. On the American side there are only a few isolated glaciers on Baffin Land, and none are known to exist in Labrador. On the American side the southernmost glacier is located on the southern side of Frobisher Bay in lat. 62°. It is evident that this difference in ice-covering is not due to the climate near the coast line, for a much greater development of glaciers is found on the side where the climate is more moderate. Possibly one of the causes for the difference is the greater humidity of the air that comes to Greenland after crossing over the waters of Baffin's and Davis' Bays; but the main cause for the difference is evidently the greater elevation of the land on the eastern side.

*Former Glaciation on the American side.**—Labrador and Baffin Land have been recently glaciated. So recent was this time of glaciation that at Turnavik Island, on the Labrador coast, glacial striæ still remain distinctly on the exposed rock-faces. The violent frost action on Baffin Land has in most cases removed the striæ; but the form of the hills, and the presence of erratics on the surface, show recent glaciation. Comparing the conditions seen here with those of New England, it seems certain that the glacier has left this northern region more recently than New England.

Changes in Level of Baffin Land.—Before the ice covered this land it was much higher than now. The evidence of this is as striking as that on the coast of Maine. The land valleys are in all stages of submergence; in Hudson Straits there are entirely submerged strike valleys, others into which the sea enters, and still others entirely above the sea level. The fjords, the nearly land-locked bays and sounds, and the land valleys extending beneath the sea, make this coast one of the most irregularly indented shores in the world. It is possible to navigate for fifty miles behind the land on the southern side of Cumberland Sound, being all the time behind hills which reach five hundred or a thousand feet above the sea.

It is practically certain that the glacial conditions came when this land was higher. When the ice disappeared the ancient highland was reduced in elevation, and the level of the hills was lowered three or four hundred feet below the surface of the sea, for beaches are found at this elevation, in various parts of

* Tarr, Am. Geol., 1897, xix, 131 and 191.

Baffin Land.* Perhaps in this depression is found a potent cause for the disappearance of the ice sheets.

Now the American land is engaged in the reverse movement of uplift. It stood three hundred feet lower at a time so recent that the boulder beaches are distinctly visible, and the individual boulders scarcely injured by the action of the weather in this region of extremely violent frost work. Their surfaces bear lichens, but they are still rounded, and they lie directly on the surface, with scarcely any soil accumulation since they became a part of the dry land. Very recently this land was moving upward, for there are beaches directly above the present ones, and yet so closely connected with them that at first it seemed that they must be forming even now. This is in harmony with the evidence obtained by Dr. Bell on the shores of Hudson's Bay.

Relation of Changes in Level to Glaciation.—Elevation is a potent cause for glaciation. Baffin Land and Labrador have been glaciated in a recent period, during a time when the land stood a thousand feet or more above the present level. The ice of this period disappeared when the land was lowered, and possibly *because* it was lowered. Now the land is rising: at present the climate is so rigorous that even with the present elevation the conditions are nearly severe enough for glaciers to develop, and in some places they do actually exist. Even near the sea level the snow banks do not disappear before the first of August, and snow commences to fall in the autumn as early as the middle of September. So far as I can estimate from my short visit, it seems that there must be places not far above the sea level where even now the snow stays throughout the summer. A slight change in climate is all that is needed to increase the number of these, and to add to their area and depth until glaciers begin. The elevation needed for this increased rigor cannot be many hundred feet in the higher regions.

Such elevation, if widespread (and the recent uplifts have extended over a broad area), would remove another of the causes for moderation in this northern climate, namely the disappearance of some of the neighboring water: the recent uplift in Baffin Land has added a large amount of land to the former area, even though the elevation has been only about three hundred feet. This uplift has so decreased the depth of some of the bays and straits that an additional elevation of three hundred feet would very perceptibly reduce the amount of water both north and west of Labrador. This added land

* The question of the elevated beaches of Baffin Land is discussed by Mr. T. L. Watson in a paper published in the Journ. of Geol., 1897, v, 17.

and decreased water area would increase the rigor of the climate.

The point which I wish chiefly to make is that the climatic conditions of Baffin Land and Labrador are wonderfully near those which produce glaciation. I would not predict that these lands are about to enter into a glaciated condition again, but it is safe to say that if the elevation now in progress continues, the time is not far distant when valley glaciers will again come in the Labrador peninsula and when those of Baffin Land will increase in extent, provided of course that there are no general changes of climate in progress, the nature of which we do not understand. From this condition of local glaciation to a general ice sheet, spreading over the land, the step is not great.

While upon this topic, and in conclusion, it may be pointed out that in addition to the moderateness of the summer climate of the Greenland coast, there is also a submergence of the land at present in progress. Topographical evidence of this is plain in the places which I visited, and the Danes have proved the point for at least some portions of the coast. Accompanying this subsidence, the Greenland glacier has recently withdrawn, at least from the land of the Upper Nugsuak peninsula, and the amount of withdrawal has been great indeed. Even now the ice-front at this point is moving backwards.

Is Greenland now passing through the stage of ice-withdrawal from which the American, Labrador and Baffin Lands have so recently escaped? and is there any relation between the down-sinking of Greenland and the uprising of Labrador and Baffin Land? Is the ice-withdrawal directly due to the land movement, and is the load of ice really the cause for the sinking which allows its withdrawal? that is, does the ice increase in area and extent with no other result than its own destruction by depressing the land, and hence removing the cause of supply? These questions very naturally arise and others even more speculative come to mind; but as their answer is not definitely at hand they may well be left as mere queries.

Ithaca, N. Y.

ART. XXX. — *On the Foramina perforating the Cranial Region of a Permian Reptile and on a Cast of its Brain Cavity;* by E. C. CASE.

DURING the spring of 1896 the author collected from the Middle Permian of Texas the nearly complete skeleton of a reptile (*Dimetrodon incisivus* Cope) belonging to the *Pelycosaurian* group of Cope's order *Theromora*. It has recently been shown* that the order *Theromora* has no existence and that the *Pelycosauria* are merely specialized *Rhyncocephalians* closely allied to *Palæohatteria*.

The cranial region in the specimen is especially well preserved and permits a close study of the different foramina. The bones are all in their natural relations and nearly free from distortion, so that the brain cavity when freed from its enclosed matrix showed its natural form. The occipital region closely resembles that of *Sphænodon*. The condyle is formed by the exoccipitals and basioccipital. The exoccipitals meet in the median line above, excluding the supraoccipital from any part in the foramen magnum. Laterally they join the expanded proximal ends of the paroccipitals. The supraoccipital is a triangular plate inclined forward as it ascends and joining by the base of the triangle the parietals above. Laterally it joins the paroccipitals and inferiorly the exoccipitals. The paroccipitals are expanded proximally, joining the supraoccipital and exoccipitals. Distally they are elongated outwards, backwards and downwards and join the greatly flattened quadrates. The lower edge of the proximal end is marked by a notch which, in union with similar notches in the basioccipital and petrosal form the fenestra ovalis. The paroccipitals remained free during life or until advanced age. This feature is found only in turtles and the young *Sphænodon*. It has been noticed in young lizards before leaving the egg.† The basioccipital forms the lower portion of the condyle and lies between the exoccipitals and paroccipitals. The lower surface is trough-like for its posterior half and supported a posterior extension of the basisphenoid. Laterally a slight notch forms the inner wall of the fenestra ovalis. Anterior to the horizontal, trough-like portion the inferior surface rises sharply; the angle thus formed is marked by a large foramen through which the hypophysis passes into the interior of the

* Baur and Case: On the Morphology of the Skull of the Pelycosauria, and the Origin of the Mammalia, Anat. Anz., xiii, Nr. 4 and 5, 1897.

† Siebenrock, F.: Das Skelet der Lacerta Simonyi Steind. und der Lacertiden familie überhaupt; Sitzunberichten der kaiserl. Akademie der Wissenschaften in Wien. Mathm. Naturwiss. Classe., ciii, Abth. I, April, 1894.

basioccipital, fig. 3, *Hy . F.* The petrosals join the paroccipitals, exoccipitals and the basioccipital, but the sutures are not distinguishable. The lower part of the anterior edges were continued forward as long processes, the anterior inferior processes of Siebenrock.* These are partially destroyed in the specimen. A deep notch in the anterior edge of the petrosals just above the origin of these processes, the *incisura otosphenoidea* Sieb., marks the point of exit from the brain cavity of the fifth pair of nerves (trigeminus), fig. 3, 5. The superior end of the anterior edge is separated from the supraoccipital by a notch which is continued on the sides of the bone as a shallow, short groove. The posterior edge contributes the last portion to the walls of the fenestra ovalis.

The basisphenoid remained free. The posterior edge is greatly thickened vertically and its lower edge stood well away from the basioccipital. The otic region and the posterior edge of the basisphenoid were covered with a large mass of cartilage. The lower surface of the basisphenoid is excavated by a deep pit, fig. 2, *Eu*, which opens on the posterior as well as the inferior surface of the bone and divides the posterior into two parts. The upper edge of the posterior surface, forming the base of the pit, was continued backward as a spout-like process articulating with the lower surface of basioccipital. The anterior edge is extended forward as a parasphenoid rostrum originating between the short and stout pterygoid processes.

The foramina penetrating these bones are remarkably similar in position to those penetrating the same bones in *Sphænodon*. The condylar foramen transmitting the twelfth pair (hypoglossus) penetrates the exoccipital just anterior to the edge of foramen magnum. Its outer end opens in a notch (the *incisura venæ jugularis* Sieb.) in the side of the exoccipital. A little below and further forward a second and much smaller foramen opens in the same notch; this may transmit either the ninth or tenth pair of nerves or a minor blood vessel. Passing forward the notch deepens and is very soon converted into a foramen by the adjacent portion of the paroccipital. This is the *foramen venæ jugularis* of Siebenrock and transmits the jugular vein and either the ninth or tenth nerves or both of them. In *Sphænodon* the foramen transmits not only these but the twelfth pair as well, the nerves being separated from the vein by very thin walls of bone and may be separated from each other or have a common canal. The opening of the twelfth pair into the notch which forms the beginning of the

* Siebenrock, F.: Zur Osteologie des Hatteria-Kopfes ibid., Bd. cii, Abth. 1, June, 1893.

jugular foramen is then very similar to the condition found in *Sphænodon*.

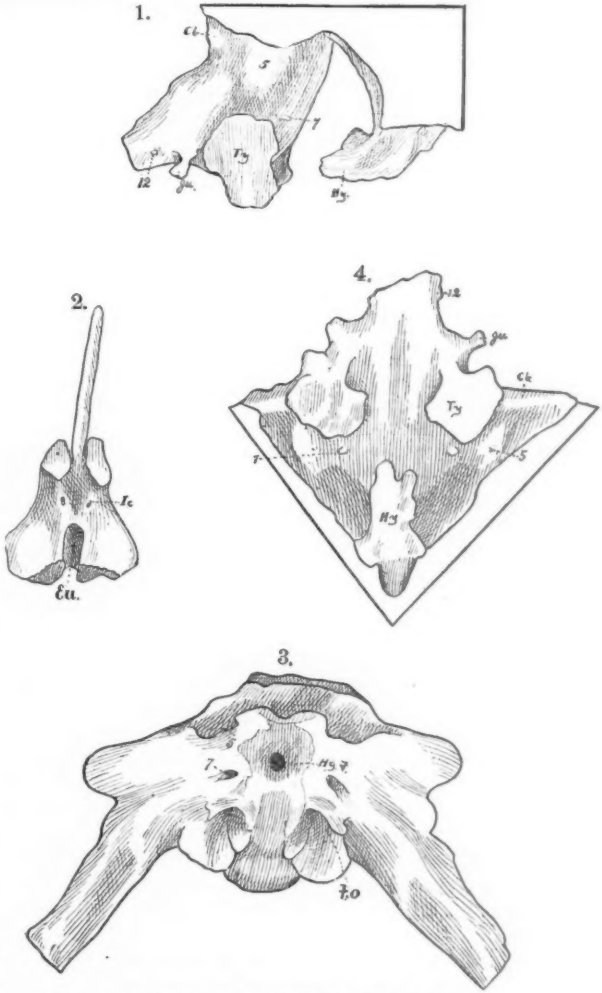


FIG. 1. Side view of a cast of the brain cavity.
FIG 2. Lower view of the basisphenoid.
FIG. 3. Lower view of the cranial region.
FIG. 4. Lower view of the cast of the brain cavity.

5. The trigeminus nerve. *T.* The facial nerve. 12. The hypoglossus nerve. *Ju.* The jugular foramen. *Ty.* Cast of tympanic cavity. *Hy.* Hypophysis. *Hy. F.* Foramen penetrating base of basioccipital. *F. O.* Fenestra ovalis. *I. C.* Foramina for internal carotids. *Eu.* Opening of eustachian tubes. *Cb.* Cerebellum.

The fenestra ovalis, fig. 3, *F. O.*, is a single opening leading by a very short canal directly into the brain cavity, a character found in fishes and the amphibian *Menopoma* and existing imperfectly in some recent reptilia, as the turtles. The same thing is described by Cope as existing in another Permian reptile, from the same horizon as the present specimen, but belonging to a separate family, the *Diadectidæ*, and his order *Cotylosauria**.

The foramina for the seventh (facial) pair of nerves appear on the outer surface of the petrosal just anterior to the fenestra ovalis, fig. 3, 7. They are located relatively a little further back than in *Sphænodon*. On the inner face of the same bone the foramina appear at the side of the base of the brain cavity a little anterior to their external opening. They are located just anterior to a slight ridge which defines the limits of the tympanic cavity. In *Sphænodon* this is about the point of location of a foramen common to the seventh and eighth nerves, which, however, almost immediately divides, the posterior branch penetrating the inner wall of the tympanic cavity and leading the auditory nerve to the inner ear.

The foramen for the fifth (trigeminus) nerve is completed from the incisura otosphenoidea by the membranous wall of the anterior portion of the brain case, as in *Sphænodon* and many lizards. Fig. 3, 5.

The deep pit excavating the lower surface of the basisphenoid is in all probability the lower opening of the eustachian tubes. In most reptilian forms the tubes pass into the pharynx in the neighborhood of the basioccipital-basisphenoid suture and anterior to the fenestra ovalis. In the crocodilia and the aglossal batrachians they have a common opening into the mouth. In the present form the tubes probably penetrated the large mass of cartilage covering the otic region and the posterior end of the basisphenoid and found a common opening in the deep pit described. It is difficult to imagine the use of such an extensive cavity in the basisphenoid, but in the *Teleosauria* an equally large cavity is found roofed over with bone. Anterior to this pit two foramina, fig. 2, *I. C*, penetrate the lower surface of the basisphenoid bone and on its upper surface a large foramen appears just posterior to the origin of the presphenoid rostrum. Through the pair on the lower surface the internal carotid arteries enter the bone and through the upper it gains access to the brain cavity by way of the pituatary fossa. On either side of the single foramen a pair of small foramina carry branches of the internal carotid. All of

* Cope, E. D.: On the Structure of the Brain and Auditory Apparatus of a Theromorphous Reptile of the Permian Epoch, Proc. Am. Phil. Soc., vol. xxiii, 1885.

these foramina are very similar in position to the same ones in *Sphænodon.*

The cast of the brain cavity shows fairly well all parts posterior to the fifth pair of nerves, and the hypophysis anterior to them. As is well known, the brain in the reptilia does not fill the brain cavity but is supported by a mass of connective tissue carrying lymph and fat masses, so a cast of the brain cavity does not give an exact copy of the brain; however many points can be brought out by such a cast.

If the cast be held with the short terminal portion of the medulla horizontal, the lower surface pitches downward at a sharp angle to a point anterior to the tympanic region and then ascends as sharply to the point of origin of the hypophysis. The superior surface is horizontal and arched from side to side to a point over the tympanic cavity and there turns upward at an angle of 45°. The angle thus produced is marked by a low, narrow ridge running across the cast and marking the position on the brain of a narrow and elevated cerebellum, figs. 1 and 4 *Cb.*, such as occurs in *Sphænodon.* This region was probably the seat of a large amount of connective tissue and it is probable that the upper surface of the medulla descended at as sharp an angle as the lower. This would make still more marked the resemblance to *Sphænodon* and to the cast figured by Cope.* This sharp bend of the medulla downward is not found in other forms, though in the brain of Chelonia and some lacertilia a bend is apparent.

The sides of the medulla show most posteriorly the beginning of the twelfth nerves, figs. 1 and 4 (12), anterior to these the cast of the jugular foramen, figs. 1 and 4, *Ju.*, and finally the large casts of the tympanic cavity, figs. 1 and 4, *Ty.* The nature of the matrix and the cavities prevented the tympanic cavities being cleaned so that the semicircular canals could be determined, but it is probable that they were very similar to those described by Cope.

Anterior to the tympanic casts a sharp constriction marks the ridge defining the limits of the tympanic cavity and then a sharp outswelling the point of exit of the trigeminus nerve, figs. 1 and 4 (5). Near where these leave the body of the cast a small stub on each side marks the origin of the seventh pair, figs. 1 and 4 (7).

The hypophysis is the most interesting feature of the brain. Descending between the anterior inferior process of the petrosal and turning posteriorly, it occupies a small notch in the posterior edge of the upper surface of the basisphenoid and then passes directly into the body of the basioccipital through the foramen mentioned. In the *Crocodilia* a somewhat similar condition exists. The basisphenoid is excavated for a con-

* Baur and Case, loc. cit.

siderable extent to accommodate the hypophysis. This makes it probable that the excavation of the bone is merely a secondary character to make room for the hypophysis, for in the *Crocodilia* the basisphenoid takes a large part in the floor of the brain-cast, and in the present form it is pushed so far downward that it is excluded and the hypophysis encounters the basioccipital as soon as it turns toward the rear.

Marsh (* and †) has described in the family *Atlantosauridæ* of his suborder *Sauropoda* of the *Dinosauria* a condition in which the pituatary cavity becomes a canal perforating the basisphenoid and opening into the pharyngeal cavity, considering it an embryonic character such as exists in the chick at the fifth day of incubation.*

If the hypophysis occupied the entire cavity in the basioccipital it extended back nearly as far as the tympanic region and much further back than in most reptilian forms. In *Sphænodon*, the *Crocodilia* and some amphibians it reaches well back, but not so far as in the present form.

Compared with *Sphænodon*, the specimen shows the following points of resemblance. The foramina for the blood vessels and nerves are almost identical in position and nature. The contour of the medulla and cerebellum was similar and the hypophysis extended far back. The only point of difference is the excavation of the basioccipital to receive the distal end of the hypophysis. The free communication of the tympanic cavity is a character which is found in many existing primitive forms and is of secondary importance.

The points here brought out confirm the close relationship of the *Pelycosauria* to the primitive *Rhyncocephalia* already asserted by Baur and Case.‡

* Marsh, O. C.: Principal Characters of American Dinosaurs, this Journal, vol. xxvi, August, 1883.

† Marsh, O. C.: American Dinosaurs, Sixteenth Annual Report U. S. Geol. Survey, 1896.

‡ Baur and Case: On the Morphology of the Skull of the Pelycosauria, and the Origin of the Mammalia, Anat. Anz., xiii, Nr. 4 and 5, 1897.

Paleontological Lab., Univ. of Chicago, January, 1897.

ART. XXXI.—*The Temperature and Ohmic Resistance of Gases during the Oscillatory Electric Discharge;* by JOHN TROWBRIDGE and THEODORE WM. RICHARDS. With Plate VI.

IN our papers upon the spectra of argon and the multiple spectra of gases,* we have emphasized the importance of considering the electrical condition of the circuit in which is placed the Plücker tube containing the gas under examination. We have pointed anew to the fact that in general the continuous discharge of an accumulator produces one spectrum while the oscillatory discharge of a condenser produces another. In considering this question one is immediately struck by the fact that, although the gas acts as if it presented a resistance of several hundred thousand or even several million ohms to the current while under the influence of the continuous discharge, nevertheless this same tube allows oscillations which are wholly damped by a few hundred ohms to pass through it under the influence of a condenser. These considerations led us to measure the resistance of such a tube to the oscillatory discharge, and we found by means of a novel method that in fact *a mass of gas at low tension contained in a capillary tube may act as though it opposed a resistance of only five or six ohms to the spark of a large condenser.*

In order the more clearly to grasp the situation, the potential differences between the ends of the tube during a continuous discharge may well be considered first. A number of measurements of such potential differences have been made by Hittorf† and others, but it may be well to give two of the many series of measurements which we have made, in order to facilitate comparison with the discharge of the condenser through the same tubes. The tubes employed throughout this research were of the ordinary type devised by Plücker, consisting of two cylindrical bulbs separated by a capillary $1{\cdot}3^{mm}$ in diameter and 7^{cm} long. The electrodes were of aluminum. Unless otherwise stated, all the experiments here recorded were made with tubes of exactly this shape and size; and most of the experiments were made with a single tube. The voltmeter used for measuring the potential differences was a Thomson electrostatic electrometer, and the current used was not much over a milliampere.

As the voltmeter was only graduated to 1800 volts, the readings above that amount are merely approximations.

* This Journal, vol. iii, pp. 15 and 117, 1897.
† Wied. Ann., xx, 705.

Potential differences between electrodes of spectrum tube.

Hydrogen.		Nitrogen.	
Pressure in mm	Voltage.	Pressure in mm	Voltage.
7·0	2600 (?)	8·5	very high.
6·0	2100 (?)	5·	very high.
4·0	1900	4·	2600 (?)
3·5	1500	3·	2100 (?)
2·0	1340	2·5	1750
1·5	1260	1·7	1600
1·25	1220	1·4	1410
1·15	1150	1·2	1340
1·00	1100	1·0	1180
·70	1140	0·7	1140
·50	1220	0·6	1080
·13	very high	0·5	1040
		0·3	980
		0·25	1030
		0·13	1700
		0·06	2800 + (?)

Each gas evidently has its minimum of potential difference, that of hydrogen lying at about 1 millimeter of pressure, and that of nitrogen at about 0·3 millimeter. These minima, as well as the total potential differences, are undoubtedly modified by the strength of the current; but the results given above are comparable with one another because they were all made under the same conditions. Hittorf found a minimum at about 0·35 millimeter for nitrogen, and he pointed out by means of his extra electrodes that the fall of potential was very irregular, the greater part of it residing at the cathode. His results have been confirmed by others, and Wood* has shown that the heat evolved at different parts of the tube follows the same irregularities as these potential differences.

Neglecting the factors of the potential difference which reside at the electrodes, the sum of which increase with the exhaustion of the tube, we find that according to Hittorf's results the resistance of the gas itself steadily diminishes as the exhaustion proceeds. For example, with a current of two milliamperes he found a fall of potential of about 120 volts between two parts of the middle of the tube eight centimeters apart, the tension of the nitrogen being 0·35 millimeter. When the current was about one milliampere and the tension of the gas was only about $0{\cdot}001^{mm}$ the voltage sank to fifteen. These two figures correspond to resistance of 60,000 ohms and 15,000 ohms respectively, the resistance of the gas diminishing as the pressure is decreased. Of course we have no certainty as to how much of this opposition to the current is due to true

* Wied. Ann., lix, 238.

resistance and how much to a kind of polarization, but it is convenient for present purposes to count it all as resistance.

In any case this opposition, if maintained, is far too great to permit the passage of oscillations, even under the most favorable conditions. In order to prove that the opposition is not maintained, but is in fact broken down by the spark, it was only necessary to photograph the discharge with the help of a rapidly revolving mirror, after the method of Feddersen. Unfortunately the light in the tube itself is too faint for direct instantaneous photography; but the light of the spark between two cadmium electrodes in the same circuit is quite bright enough for the purpose, and of course any oscillations which crossed the spark gap must also go through the tube. Our next step was, therefore, to make a series of such photographs of a spark discharged through hydrogen, at first when the gas glowed with a white light and showed its many-line spectrum, and afterwards, when it exhibited the characteristic red tint and a spectrum of only four lines in the visible portion of the spectrum.

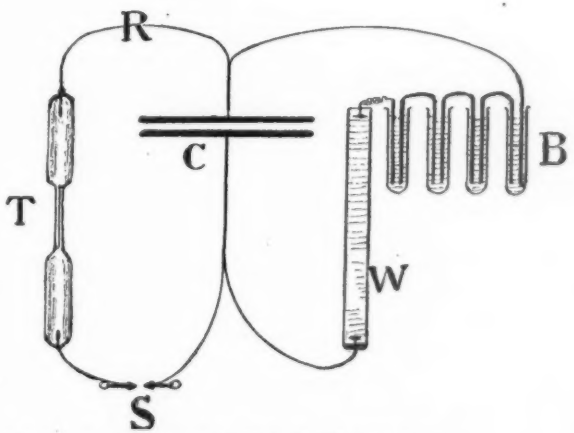


FIG. 1. B = Battery of 5,000 to 10,000 storage cells.
C = Condenser of 1,000 to 18,000 electrostatic units.
R = Small resistance to damp oscillations.
S = Spark gap between cadmium terminals.
T = Plücker tube containing gas.
W = Chief water resistance of 5 to 50 megohms.

In order to obtain the white light in the hydrogen tube, it was necessary to increase either the impedance or the resistance in the circuit containing the tube. With a definite very small amount of impedance we increased the resistance until the

red glow disappeared in the tube, and discovered, on developing the photographs which were obtained by means of the revolving mirror, that the discharge was non-oscillatory. When, however, the resistance in the condenser circuit was diminished, the red glow began to appear, and the photographs taken when all the resistance except the tube itself was removed showed that the discharge was oscillatory. This also was evident from the peculiar crackle of the spark, which Hertz remarked was essential in performing his experiments on electric waves. The apparatus used in this and subsequent experiments is sketched in the accompanying diagram (fig. 1). An examination of our photographs showed the interesting fact that there were in general not more than two or three complete oscillations; the remaining ones which could have been obtained from the given capacity and self-induction having been damped by the resistance of the gas. The question immediately arose: what is the resistance of the gas at the instant of the discharge? For if an idea of this can be obtained we can get an estimate of the amount of heat developed in the gas during each oscillation. A Thomson electrostatic voltmeter connected to the ends of the hydrogen tube indicated a difference of potential of over 1,800 volts, and this difference of potential could only be obtained by substituting for the Geissler tube a resistance of many thousand ohms. The indications, however, of this instrument in this case are of no value; for we discovered that a resistance of from ten to twenty ohms was sufficient to produce the same amount of damping which the gas exerted. The resistance of the gas, therefore, could not be greater than these amounts.* It is evident, therefore, why the voltmeter gives erroneous readings. On account of the inertia of the moving parts and the very short time of the discharge, it does not indicate the fall of potential through the small resistance of the tube during the instant when the discharge passes, but maintains an indication of a high difference of potential.

In order to apply systematically this new method of measuring resistance, our next step was to prepare a series of standards,—photographs of the oscillatory sparks of condensers of different sizes, damped by known resistances, which were substituted for the Geissler tube in the condenser circuit. In all these experiments, of course, the small resistance on the left hand side of the sketch was cut out by a suitable key. Three large Leyden jars, each 30 centimeters in diameter and 50 centimeters high, having a capacity of 6,000 electrostatic units apiece, were used either singly or together to act as the condenser; the waves generated by these large capacities were

* Damping of electrical oscillations, Proc. Am. Acad., 1891.

much too long to interfere with one another upon so short a circuit. The resistances were wires of manganin $0{\cdot}2^{mm}$ in diameter, stretched on both sides of long strips of thin vulcanite plate, the idea of this arrangement being to eliminate self-induction and yet to prevent the short-circuiting of the high potential. The spark gap usually consisted of cadmium terminals arranged in the focus of a revolving mirror driven very rapidly by means of a small electric motor. In a few cases zinc terminals were used, with no appreciable difference in the results (Rhigi*). The terminals were re pointed from time to time and were always kept at a distance of 1·3 millimeters apart. With this apparatus the photographs of perhaps five hundred sparks were taken; and the results are recorded in the following table. As a general rule the spark containing the highest number of oscillations upon any plate was taken as the representative one.

The first column below records the resistance through which the discharge had to pass before reaching the spark gap, while the second, third and fourth record the number of half oscillations observed upon the photographs.

These figures correspond in general tendency with the less precise determinations made by Feddersen;† they show, as his determinations did, that the larger the capacity, the fewer the number of oscillations. This tendency is especially noticeable between two and ten ohms, the part of each curve which is most capable of accurate determination. While not perfectly regular, these curves manifestly furnish the means of measuring approximately any small resistance through which a spark, followed by as much as one-half of an oscillation, is able to pass.

Having now our scale of measurement, we substituted for our known resistances a Plücker tube attached to an admirable automatic Toepler air-pump (of Kiss, Budapest), as well as to receivers containing pure hydrogen and nitrogen. These gases could be delivered individually into the tube at any desired pressure. The bulbs of the pump, aggregating over a liter in volume, were always in communication with the Plücker tube, while the circuit was closed, so that the discharge took place under essentially constant pressure. The hydrogen was made electrolytically and purified by passing through a solution of potash, and over fused potash and phosphoric anhydride; the nitrogen was made by passing ammonia over an excess of heated cupric oxide, through much water, and over the same two driers as the hydrogen. The length of the spark gap remained always the same, excepting for the very lowest and the very highest pressures of gas, through which

* Nuovo Cimento, II, xvi, 97 . † Pogg. Ann., cxiii, p. 437.

Resistance Standards.

Resistance Ohms.	Capacity = 6,000. No. of half oscillations. =	Capacity = 12,000. No. of half oscillations. =	Capacity = 18,000. No. of half oscillations. =
0		37.	32
1		21.	21
2	16.	14.	13
3	12.	11.	10
4	9.5	8.5	7
5	8.	7.	6
6	7.5	6.	5
7	6.5	5.	4
10	5	4	3
15	3	3	
20	2	2	1.7
30	1	1	1

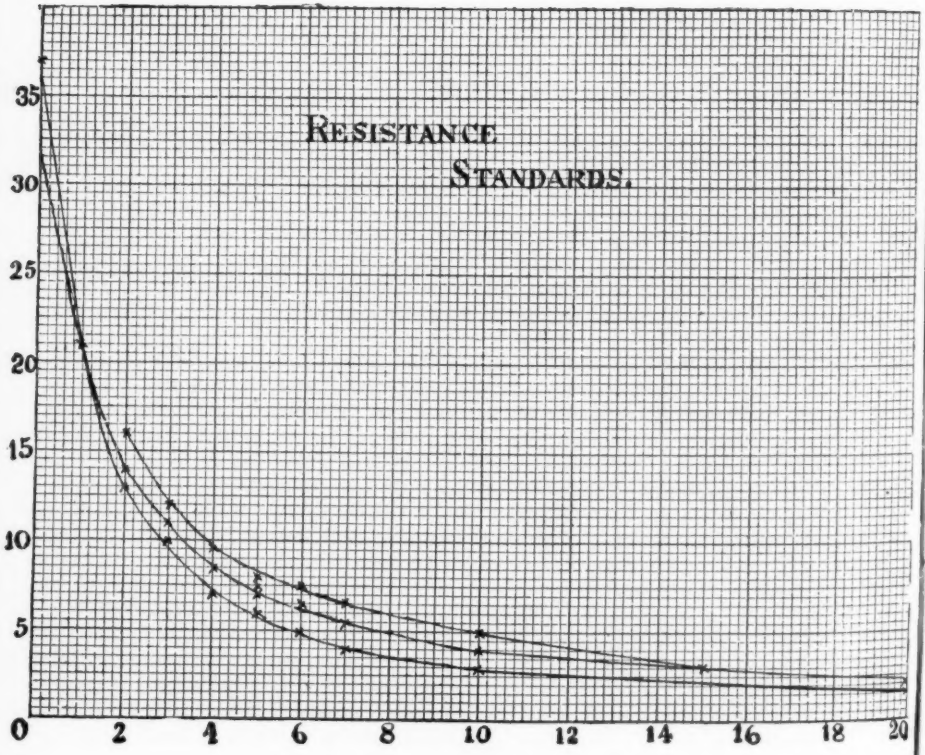
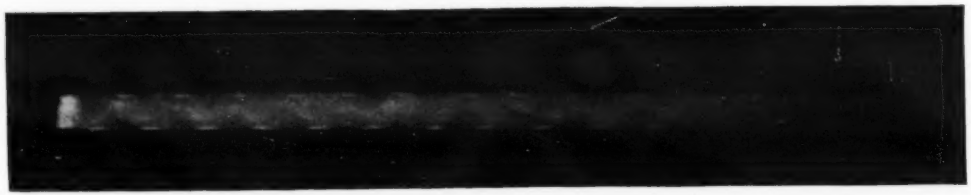


FIG. 2. Ohms are plotted horizontally.
Half oscillations are plotted vertically.

1.



2.

PHOTOGRAPHS OF OSCILLATIONS.

1.—Not damped.
2.—Damped by 5 ohms resistance of hydrogen at point of least resistance.

the electricity refused to pass unless the spark gap was narrowed.

In the first column of each table below is recorded the pressure of the gas, in the second, third and fourth are recorded the numbers of half oscillations obtained with the three different capacities respectively, while in the fifth, sixth, and seventh of these columns are to be found the resistances corresponding to these oscillations, each value being taken from its proper curve in fig. 2. In order to give a better idea of the comparison and the way in which the oscillations are damped, reproductions from two photographs are given in Plate VI.

The Resistance of Hydrogen.

Pressure of gas.	Number of half oscillations.			Resistance in ohms.		
	Capacity = 6,000.	Capacity = 12,000.	Capacity = 18,000.	Capacity = 6,000.	Capacity = 12,000.	Capacity = 18,000.
millimeters				ohms	ohms over 100	ohms
13·5		0				
10·0	$\frac{1}{2}$		2	50 ?		15
5·0	1	2	2	30	20	15
3·6		2			20	
3·0		3	3		15	10
2·0	2	3	3	20	15	10
1·8		3			15	
1·25	3	3	4	15	15	7
1·15		4			10	
0·85		$5\frac{1}{2}$			9	
0·75		$6\frac{1}{2}$			$5\frac{1}{2}$	
0·60		7	6		5	5
0·40		6			6·	
0·31	$6\frac{1}{2}$	7	6	7	5·	5
0·21		6			6·	
0·15	5		6+	10		5
0·1		$5\frac{1}{2}$ (?)			7 ?	
0·05	$4\frac{1}{2}$	no spark	no spark	11		

Besides these measurements of hydrogen and nitrogen, several photographs were made of sparks sent through some of Lord Rayleigh's argon contained in sealed tubes. Since the capillaries were not in every case equal in diameter, the results are not wholly comparable with one another or with those in the two tables given above. Two half oscillations each were

observed in the photographs of argon at 1, 2, and 3^{mm} pressure contained in tubes with very fine capillaries, while six half oscillations were observed in tubes about like those used for nitrogen and hydrogen. This shows that the form of the tube influences very materially the resistance. As a very small jar will provide enough electricity to give the blue spectrum of argon, the resistance of a tube containing the gas at 1^{mm} pressure was determined with a capacity of about 1,000 as well as with the usual capacities 6,000, 12,000 and 18,000 electrostatic units. Somewhat over six half oscillations were observed in each case, corresponding to resistance of about thirteen, eight, six-and-a-half, and five ohms respectively. In all, about a thousand photographs of sparks through the various gases were made.

The Resistance of Nitrogen.

Pressure of gas in millimeters.	Number of half oscillations.			Resistance in ohms.		
	Capacity = 6,000 units.	Capacity = 12,000 units.	Capacity = 18,000 units.	Capacity = 6,000	Capacity = 12,000	Capacity = 18,000
				ohms.	ohms.	ohms.
9·5		1			30	
5·0	1 (faint)	1½	1½	35	25	23
4·2		1½			25	
2·7	2		3	20		10?
2·	2	2	2(?)	20	20	15
1·7		3			15	
1·3		3			15	
1·04	3	4	3½	15	10	8
0·70		4			10	
0·50	3½	5	4		8	7
0·30	4		6	12		5
0·26	5½		5½(?)			5·5
0·22		8			4·5	
0·15	6½	8½		7	4	
0·07	5	8		10	4·5	
0·05		7			5	
0·03		8			4·5	
0·02		5			8	
0·01		5			8	
0·005	no spark	no spark	no spark	—	—	—

The evidence of all these experiments is unequivocal, and may be summed up under the following heads:

I. *The resistance of a gas at low pressure to the oscillatory discharge is equivalent to only a very small ohmic resistance.*

II. *This resistance is in general greater, the less the quantity of electricity.*

III. *Down to a very small pressure, this resistance decreases with the tension of the gas.* At a pressure considerably below the minima in the potential curves given on p. 328 the resistance seems to reach a minimum, but the irregularity of the sparks in this region make this last minimum somewhat uncer-

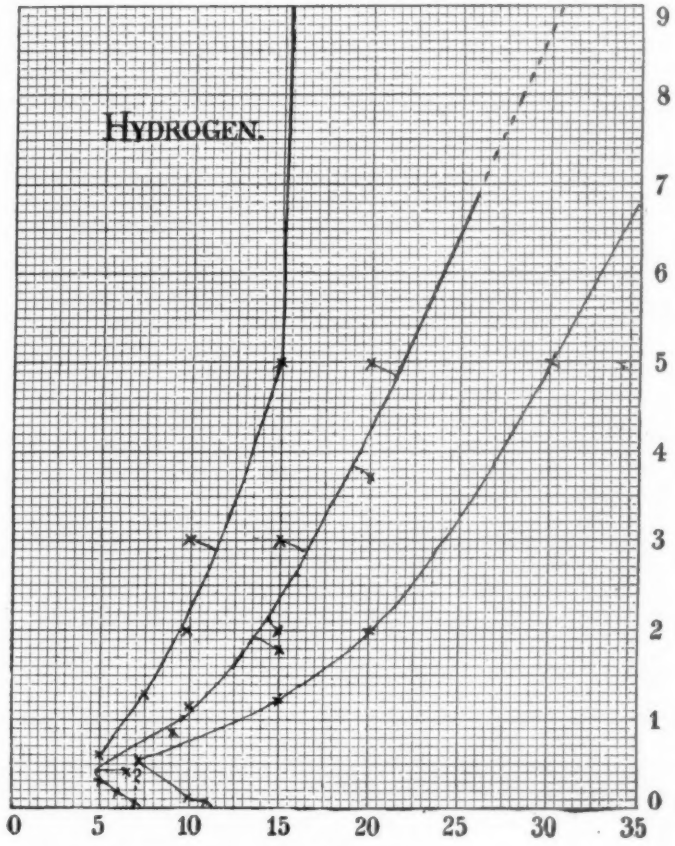


FIG. 3. Ohms are plotted horizontally.
Millimeters of pressure are plotted vertically.

tain. The minima of resistance probably vary with the quantity of electricity discharged as well as with the specific properties of the gas. The minimum for nitrogen is attained at a much lower pressure than that of hydrogen.

IV. *The form of the tube has an important effect upon the resistance of the gas.*

V. *With the oscillatory discharge it is evident that the electrodes produce far less effect than with the continuous discharge.*

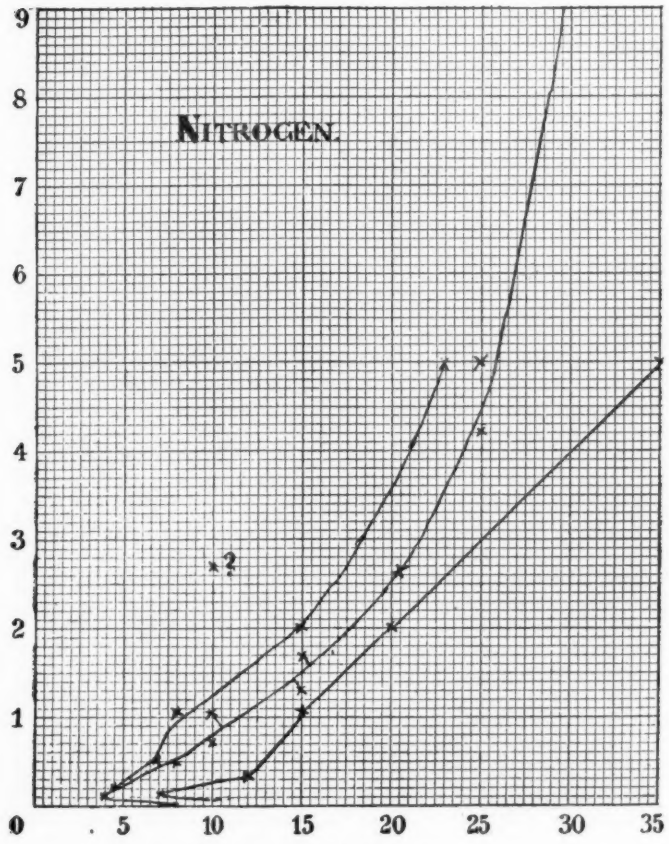


FIG. 4. Ohms are plotted horizontally.
Millimeters of pressure are plotted vertically.

These conclusions are not wholly without support in the literature of the subject. J. J. Thomson's researches with tubes without electrodes* show that a rarified gas must have

* Recent researches in electricity and magnetism, p. 92. This book contains an admirable résumé of the whole subject.

an extremely low resistance to the oscillatory discharge of electricity, and Jaumann* found that the "electric strength" of a gas increased as the quantity of electricity diminished. But all earlier accurate measurements have been made with continuous currents, whose relations are very different from those of the sudden discharge of a condenser which we have studied. The continuous current meets with great opposition, especially at the negative electrode, where much heat is developed. The oscillatory discharge meets with very little opposition, and correspondingly we find that here the greatest heat is developed in the gas itself, especially in the capillary tube, the electrodes remaining comparatively cool. This experiment we have tried repeatedly, sending exactly equal quantities of electricity through the tube in each fashion, and observing great differences in the heating effects. Moreover, even in the continuously glowing gas itself, apart from the electrodes, the potential difference, if due to resistance alone, corresponds to a vastly greater resistance than that opposed to the condenser discharge, according to Hittorf's results, already quoted.

It is clear that the quantity of electricity going through the tube in a given time is almost incredibly different in the two cases. This difference has not been enough emphasized in the literature upon the subject. Supposing that the battery and other resistance are so regulated as to supply a milliampere of current, and the condenser is of such a size that when it is connected the spark passes ten times a second. These conditions were frequently those of our experiments. The spark, judging from our photographs, certainly does not last more than one millionth of a second, hence the current strength at the instant of the discharge must be at least 100,000 times as great as that of the continuous discharge without the condenser, or must amount to 100 amperes.

Jaumann's observation that the opposition to the current is less as the current increases, and our conclusion (III) that the resistance is less with the larger capacity, are in reality observations which may be represented as the two extremities of a long curve. This curve is formed by the relation of milliamperes to megohms on one end, and of hundreds of amperes to ohms upon the other. The part of the curve between these two extremities is very hard to investigate with our present means, and indeed it seems to behave differently with different gases. For these two conditions are represented in any given case by the two spectra of the gases, and as we increase the current we observe varying relations between these spectra. In the case of hydrogen the spectrum of four

* Sitz. Berichte, Wien Akad., vol. xcvii, p. 765.

visible lines gradually increases in brilliancy with the gradual fading of the many-lined spectrum of the lower temperatures as the current is increased; and only when the current strength becomes very great do the extra lines disappear. In other words, the change from one condition to the other is gradual. In the case of nitrogen, on the other hand, the change is abrupt; and often when the gas is near its sensitive point some sparks will go through with little opposition, while others give the banded spectrum and the non-oscillatory photograph, showing that the resistance was large. Argon is like nitrogen in the suddeness of the transition, but its transition takes place with much weaker currents than with either hydrogen or nitrogen. We have repeatedly found argon to give the pure blue spectrum under the influence of the discharge of the full battery with very little resistance in the circuit without any condenser, or with less than eight amperes; for the resistance of each cell of the battery is about the quarter of an ohm.

One of the great difficulties of investigating the intermediate part of the curve lies in the fact that no tube is strong enough to stand the continuous application of temperatures as high as those developed by the corresponding current. On the other hand, the repeated instantaneous discharge, which the tube will stand, cannot be estimated when the resistance rises above the very small amount necessary to damp out the oscillations.

The question whether the change in the spectrum upon increasing the current, is due to greater heat or to the oscillatory motion, is one which is not easily settled, because the last trace of the return oscillation requires hundreds of ohms for its damping; and under these conditions this oscillation is not easily photographed. The fact that argon offers no less resistance than hydrogen or nitrogen to electric oscillations, but nevertheless is much more sensitive to increased current, tends to show that the important factor in the question is not the oscillatory nature of the discharge, but only the great quantity which is always attendant upon oscillatory discharges.

Since gases do not strictly follow Ohms law, we cannot assume that the formula $R=\sqrt{\frac{4L}{c}}$ in which R is resistance, L=self induction, and c=capacity, and which gives the limiting value of R for non-oscillatory discharges, rigidly holds. If, however, we obtain a white glow in hydrogen gas due to the unidirectional discharge of a large condenser through a large outside resistance and then proceed to increase the electromotive force, and consequently the strength of the current in our unidirectional discharge, we can determine whether this form of discharge is competent to produce the red glow in hydrogen. The apparatus which was used for this purpose

consisted of a step-up transformer consisting of two secondaries of many turns of fine wire which were slipped upon a long primary. When the secondaries were coupled in series the electromotive force of the discharge was doubled. without any considerable change in the capacity. As a matter of fact, the glow was seen to be perceptibly redder with two coils than with one, showing that the change in the quantity is the essential feature in the change of the spectrum.

While this conclusion interferes with the strict application of the word talantoscope to an argon-tube, the use of the tube as a talantoscope, nevertheless, remains; for while the oscillations and the blue spectrum are not strictly dependent upon one another, they are both dependent upon the same final cause.

The conclusion that the large quantity of electricity, and therefore, the high temperature caused by the discharge, is the cause of the very much diminished resistance of the tube and the corresponding spectrum, leads us at once to consider the energetics of the problem. On the assumption that the departure from Ohms law is not large,* since $C = \frac{E}{R}$ and the amount of the impedance in the circuit is so small as to be neglected, we shall have an amount of energy developed in the tube for perhaps the millionth part of a second equal to CE. With an electromotive force of 10,000 volts and a resistance of ten ohms, a current of 1,000 amperes must be obtained, and this multiplied by 10,000 and divided by 746 gives the electrical horse power if the current were maintained for a second. The corresponding value is over ten thousand, and this corresponds to an excessively high temperature for a very brief space of time.

Of course a bolometer or any other thermometer in the tube could not indicate this energy, for it is of very short duration and even in its brief existence undoubtedly does not affect the whole mass of the gas through which the discharge passes. J. J. Thomson has called attention to this fact.† In the case of the continuous discharge the temperature is undoubtedly vastly lower, but even here it is probable that the pale brush does not concern all the particles of the rarified gas.

* Moreover we find that the electrostatic capacity of the Geissler tube is not sufficient to affect the period of the oscillatory movement. To decide this we arranged a rocking key which interposed first the Geissler tube and then immediately afterward a wire of self-induction equal to that of the tube, and photographed the oscillatory discharge through the two circuits. No change could be perceived in the period of the two discharges. If the electrostatic capacity of a Geissler tube were large an argon tube would not be as sensitive as it is to slight changes in electrostatic capacity in the circuit.

† Recent researches, p. 167.

Therefore calculations or experimental determinations of the average temperature of a large tube, such as those of Warburg* and Wood, while interesting as relative considerations, give no clue as to the kinetic energy of the molecules which actually carry the current. For such a clue one must refer to experiments of the sort we describe.

All the results recorded in this paper support the well known hypothesis that the current when disruptive is carried by dissociated molecules. The continuous discharge is best explained by conceiving of a polarized condition, in which the molecules are in some way bound together by the electric energy which is striving to force itself through them. As the current increases, the amount of the heat increases, until it reaches a stage when some of the gas is freed from this bondage—when the molecules not only separate from their electric embrace, but split into their component atoms. Then, if a large quantity of electricity is at hand to discharge itself, the rate of discharge increases with enormous rapidity, resulting in more dissociation, and the resistance is almost entirely broken down. A good résumé of the present state of this hypothesis is given in Nature, Jan. 28, 1897, p. 310, and to this statement our determination of the resistance makes an important addition.

Hydrogen and oxygen cannot be dissociated to any appreciable extent at ordinary temperatures and pressures, otherwise water would form when they were mixed. We have no vapor densities of hydrogen or oxygen at temperatures which show dissociation, but this is no reason for believing that at temperatures of three thousand degrees or more dissociation does not take place. Indeed, the burning of hydrogen and oxygen gives us every reason for believing that the tendency of both hydrogen and oxygen molecules to dissociate increases with the temperature. Chlorine, bromine, and iodine are all known to dissociate at high temperatures, and to conduct electricity well under those conditions.

Another point in favor of ascribing the red glow of hydrogen to dissociation is to be found in the fact that rarified aqueous vapor gives the pure "four-line" spectrum much more easily than hydrogen itself. In order to give any hydrogen spectrum at all, the vapor must be dissociated. Of course the dissociation takes place only at the moment of the discharge, the atoms combining again when cold. It is caused by the heat of the discharge, and not by electrolysis, although that too may take place at the electrodes. In short, there is every reason to believe that at temperatures as high as those with which we are dealing, the hydrogen is split apart into hydro-

* Wied. Ann., liv, 265.

gen atoms, and that these atoms, or perhaps the energy involved in the act of splitting them, are responsible for the "four line" red spectrum. The fact cannot be too strongly emphasized that this sort of dissociation is very different indeed from the electrolytic dissociation of solutions.

In order to find if the structure which is dissociated by the spark is the molecule or some more complex structure, mercury vapor was subjected first to the continuous discharge and then to the oscillatory. Since the spectra obtained were widely different, the conclusion, at least in the case of the mercury, is that the structure is complex; for mercury molecules are monatomic. This conclusion is reinforced by many other facts known about the continuous discharge. Hence the existence of two argon spectra does not give any reason for disbelieving the evidence of specific heat with regard to the monatomic nature of argon.

From the point of view of a mechanical conception of the causes producing the two spectra of a gas, it is easy to imagine that when the atoms are bound together in the polarized condition, the electricity by a succession of readjustments may travel step by step from one end of the tube to the other, at a comparatively low temperature, and so cause quite a different set of electro-magnetic vibrations from those depending upon the breaking down of this polarized system. The evidence that the second spectrum given by the oscillatory discharge is due either to the act of separating the atoms from one another, or to the passage of the electricity through the atoms already set free by the heat, has been given above. Hittorf's experiments, in which he was able to send a very strong continuous current through a gas without the production of light, would seem to indicate that the light is due to energy involved at the moment of dissociation, but the spectra of the solar prominences lead to the opposite inference, and conclusive evidence upon this point is wanting. The dissimilar behavior of different gases is easily accounted for by considering the two causes which are supposed to resist the dissociation: in the first place, the "polarized" condition of the molecules, and in the next place the chemical affinity of the atoms for one another. This last force is usually admitted to be greater in the case of nitrogen than in that of hydrogen, hence the difficulty, the irregularity and the abruptness of the transition in the former case. One should expect that a monatomic gas, like argon, where the polarization alone prevents the passage of the current, would be easier to change in this respect, as indeed it is. The fact that the second spectrum of mercury is not very easily obtained, militates against this explanation, however.

Assuming, then, that the red spectrum of hydrogen is due to the sudden occurrence of the reaction

$$H_2 = H + H$$

it is very interesting to note that our results agree with the necessary deductions from the law of mass action as applied to this case. If the reaction is supposed to take place isothermally at a very high temperature, it is manifest that the progress of the reaction from right to left must increase as the concentration of the hydrogen—in other words, the tension of gas—is diminished. This we find to be the case: the resistance of the gas increases and the purity of the "four-line" spectrum diminishes as the tension of the gas increases, except when the gas is exceedingly rarified. In this last case it is probable that the number of atoms present, even if all were free, would be insufficient to carry all the current. Hence we should expect to find this minimum at a lower pressure when the capacity of the condenser employed was less; but unfortunately the spark is too uncertain at these very low temperatures, even with twenty thousand volts from the complete battery, to give definite results.

Since hydrogen undoubtedly requires a very large amount of heat for its dissociation, it follows that when the temperature is raised while the pressure is kept constant, more atoms should be set free. We find, as a matter of fact, that the resistance diminishes as we increase the capacity of the condenser—that is to say, the heat of the discharge. The case is exactly analogous to the dissociation of nitric peroxide observed by E. and L. Natanson.*

Our work leads one to infer that since a very high temperature is needed to produce the "four-line" spectrum of hydrogen, this high temperature must be present wherever this spectrum appears; for example, in the solar prominences and in many fixed stars. The higher the tension of the gas, the higher the temperature required; hence one must know the atmospheric pressures in these heavenly bodies before attempting to guess at the actual temperature attained; but there can be no doubt that this temperature is in any case far beyond the reach of any earthly means except the electric discharge which we have been considering.

* Wied. Ann., xxiv, 454, and xxvii, 606.

Harvard University, Feb. 23d, 1897.

Art. XXXII.—*Does a Vacuum conduct Electricity?*; by John Trowbridge.

This question has been answered affirmatively by Edlund, and negatively by the latest researches of Professor J. J. Thomson. Some recent experiments of my own lead me to believe that the principal resistance resides at the boundary between the highly rarified space in a Crookes tube, for instance, and the electrodes. I find by photography that the electrical discharge which produces the Röntgen rays oscillates and the number of oscillations gave in the tube experimented with a resistance in the tube at the moment of discharge of only five ohms. In the case of a disruptive discharge of electricity, therefore, after the initial resistance of the medium breaks down it exhibits hardly any resistance during the oscillations of the discharge. I produced the proper conditions by employing a Planté rheostatic machine* or in other words an arrangement by means of which Leyden jars can be charged in multiple and discharged in series. A highly disruptive spark can thus be obtained with a storage battery of ten thousand cells. This Planté accumulator does not reverse its poles and is therefore extremely useful in studying the Röntgen phenomenon. I was extremely interested, however, in discovering that the electrical discharge through the Crookes tube at the moment when the Röntgen rays were being produced most strongly was an oscillatory one, of a high period, about ten million oscillations per second in the case I examined. Perfect definition, therefore, cannot be obtained even with the use of an electrical machine unless care is taken to shield the anode from the photographic plate.

By applying the same method to electrical sparks in air, I have discovered that a spark of six inches indicates little if any more resistance than a spark of one inch. The sparks therefore do not follow Ohm's law. All my experiments lead me to believe that a disruptive discharge of electricity encounters its chief resistance at the going over layer between the electrodes and the medium; and that during the discharge in a highly rarified medium very little resistance is encountered. By the method employed an increase or diminution of resistance of half an ohm can be detected. The resistance of the Crookes tube to the disruptive discharges seems to diminish with the increase of rarefaction or the nearer we approach a vacuum.

* Comptes Rendus, lxxxv, p. 794, 1877.

Jefferson Physical Laboratory, March 9, 1897.

Art. XXXIII.—*A Note on the "Plasticity" of Glacial Ice;* by Israel C. Russell.

It is conceded, I think, by all students of glacial phenomena, that the flow of glaciers is at least analogous to the flow of plastic solids under the influence of gravity. That the flow of glaciers is due to true plasticity, however, as claimed by Forbes and others, cannot be admitted in view of somewhat recent experiments on the bending of ice by McConnell, Kidd and Mügge.*

These experiments have demonstrated that a bar of ice cut from a single crystal, with the optic axis perpendicular to two of the side faces, when subjected to a bending stress, will bend freely in the plane of the optic axis, but not at all in a plane perpendicular to that axis. In the bent crystals the optic axis in any part is normal to the bent face in that part. As stated by McConnell, a crystal when thus tested behaves as if it were composed of an infinite number of thin sheets of paper, normal to its optic axis, and attached to each other by some viscous substance which allowed one to slide over the next with great difficulty. The greatest freedom of movement was found to occur when the ice experimented on was near the melting point, and became less and less with a decrease of temperature. In certain of the experiments referred to, the freedom of movement at $-2°$ C. was twice as great as at $-10°$ C.

These experiments seem to furnish an explanation of some of the phases of glacial motion, and of the growth of the granules of glacial ice. When thin sections of glacial ice are examined by means of polarized light,† it is seen that the granules of which it is composed are fragments of ice crystals, or perhaps imperfectly formed crystals, which interlock one with another so that the structure resembles that of coarsely crystalline dolomite.

The optic axes of the granules are without orderly arrangement, but have all directions. Pressure brought to bear on such granular ice in a definite direction, would cause movement in the crystal fragments or granules, whose optic axes were in the plane of pressure, but would not change the forms of the crystal fragments not thus oriented. The crystal frag-

* J. C. McConnell and D. A. Kidd: "On the plasticity of glacial and other ice," Roy. Soc. London. Proc., vol. xliv, 1888, pp 131–161. J. C. McConnell: "On the plasticity of an ice crystal," ibid., vol. xlviii, 1890, pp. 256–260; vol. xlix, 1891, pp. 323–343. O. Mügge: "Ueber die Plasticität der Eiskrystalle," Separat-Abdruck aus dem Neuen Jahrbuch für Mineralogie, etc, 1895, Bd. II, cited in the Journal of Geology, vol. iii, 1895, pp 965, 966.

† R. M. Deeley and George Fletcher: "The structure of glacial ice and its bearing upon glacial motion," Geol. Mag. (London), Decade 4, vol. ii, 1895, pp. 152–162.

ments having their optic axes in the plane of pressure would be changed in shape, as in the experiments cited above, by movements along gliding planes.

The stresses in glaciers are manifestly in various directions, and owing to the flow of the ice, inequalities of the rock surfaces beneath, etc., must be exceedingly complex. As the crystal fragments of which glaciers are composed are without orderly arrangement, it is evident that some of them will be properly oriented to be deformed by a differential movement of their parts along gliding planes, by pressure acting in any direction. Under diverse stresses the resultant motion would be in the direction of least resistance. That is, the granular ice would behave like a plastic solid.

Owing to diversity in orientation, it follows that adjacent granules might be deformed in different directions; and that diverse movements of adjacent granules might result.

The yielding of glacial ice to pressure, we conceive, is due to movements along gliding planes in the granules of which it is composed. If this process is continued, the granules will evidently be destroyed by being divided along the planes on which movement occurs, but the resulting subdivisions—or "plates" perhaps we may term them,—are re-united probably by the process of regelation. The plates which after uniting have the same orientation, would form new granules. The longer this process is continued, or in other words, the farther a glacier flows, the greater the chances that a large number of plates will come together with similar orientation and the larger will be the resulting granules.

Under the hypothesis here suggested, the granules of glacial ice are considered as an inheritance from the granules in the ice formed by partial melting and re-freezing of névé snow. The granules at first are minute, but under the pressure of ice at higher levels they yield along gliding planes, and a resultant motion similar to that of plastic solids under like conditions is initiated. The granules are destroyed by this process, but progressive motion leads to the union of a constantly increasing number of the plates into which they are divided, and the growth of larger granules.

As movement in ice crystals, along gliding planes, takes place with increased freedom the nearer the temperature approaches the melting point, we should expect, under the hypothesis here suggested, that glacial motion would fluctuate with changes of temperature. This, as is well known, is what has been observed.

It is evident that one granule in a mass of glacial ice cannot be deformed by movements of its various portions along gliding planes, unless room for the change of form is available. As the lower extremity of a glacier is normally exposed to a

higher temperature than its upper portions, and as the freedom of motion in ice crystals is greatest the nearer the temperature of the ice approaches the melting point, we should expect, other conditions being the same, that the rate of change in the granules composing a glacier would be greatest at its lower extremity and decrease progressively toward its névé. Conditions which would permit granules to change their shape would thus be transmitted from the lower extremity of a glacier toward its source. The deformation of granules may also be facilitated by the formation of crevasses. In fact, under the hypothesis here considered, crevasses seem to be an important element in glacial flow.

Granules so situated with reference to the direction of pressure that they cannot yield along gliding planes, may be moved bodily, owing to the movements of adjacent granules, or they may be fractured and the fragments united to neighboring granules, or themselves acquire additions and form new granules. This explanation seems in harmony with what has been observed in reference to the gradual increase in the size of the granules of glacial ice with the distance it flows; and also with the fact that this gradual increase in size is accompanied by the pressure at all times of small granules.

An objection that may perhaps be advanced to the views here expressed in reference to the growth of granules, is that, owing to the flow of glaciers, the granules composing them would become similarly oriented, that is, the optic axes of the crystal fragments would all become parallel to the direction of flow. The varying stresses, due to inequalities of channel, the disturbing conditions introduced by englacial débris, inequalities in temperature, etc., would apparently lead to the growth of granules with their optic axes variously oriented.

It has been asked: "Why, if glacial ice responds to pressure like a plastic solid, do not bowlders on the surface of a glacier depress the ice beneath?" I would suggest in reply that a bowlder shields the ice beneath from the heat of the sun and thus diminishes the conditions favorable to movement along the gliding planes in the granules composing it. The ice in the shadow of a bowlder is stiffened possibly to a considerable depth, and forms a platform on which the protecting rock-mass is carried. The larger the bowlder, the broader and deeper the area of rigid ice in its shadow.

If the explanation just suggested is correct, measurements of glacial flow where narrow medial moraines occur, should show a less rapid movement than the adjacent lanes of clear ice. This and other tests—especially a study of the ice granules at many points in a glacier,—need to be made before the explanation of the plasticity of glacial ice proposed in this note can be considered as more than a working hypothesis.

Art. XXXIV. — *The Affinities of Hesperornis;* by O. C. Marsh.

In the autumn of 1870, I discovered in the Cretaceous of western Kansas the remains of a very large swimming bird, which in many respects is the most interesting member of the class hitherto found, living or extinct. During the following year, other specimens were obtained in the same region, and one of them, a nearly perfect skeleton, I named *Hesperornis regalis.** In subsequent careful researches, extending over several years, I secured various other specimens in fine preservation, from the same horizon and the same general region, and thus was enabled to make a systematic investigation of the structure and affinities of the remarkable group of birds of which *Hesperornis* is the type. The results of this and other researches were brought together in 1880, in an illustrated monograph.†

In the concluding chapter on *Hesperornis*, I discussed the affinities of this genus, based upon a careful study of all the known remains. Especial attention was devoted to the skull and scapular arch, which showed Struthious features, and these were duly weighed against the more apparent characters of the hind limbs, that strongly resembled those of modern diving birds, thus suggesting a near relationship to this group, of which *Colymbus* is a type. In summing up the case, I decided in favor of the Ostrich features, and recorded this opinion as follows:

"The Struthious characters, seen in *Hesperornis*, should probably be regarded as evidence of real affinity, and in this case *Hesperornis* would be essentially a carnivorous, swimming Ostrich." (Odontornithes, p. 114.)

This conclusion, a result of nearly ten years' exploration and study, based upon a large number of very perfect specimens and a comparison with many recent and extinct birds, did not meet with general acceptance. Various authors who had not seen the original specimens, or made a special study of any allied forms, seem to have accepted without hesitation the striking adaptive characters of the posterior limbs as the key to real affinities, and likewise put this opinion on record. The compilers of such knowledge followed suit, and before long the Ratite affinities of *Hesperornis* were seldom alluded to in scientific literature.

* This Journal, vol. iii. p. 56, January; and p. 360, May, 1872.

† Odontornithes: a Monograph on the Extinct Toothed Birds of North America. 4to, 34 plates, Washington, 1880.

Several times, I was much tempted to set the matter right as far as possible by reminding the critics that they had overlooked important points in the argument, and that new evidence brought to light, although not conclusive, tended to support my original conclusion that *Hesperornis* was essentially a swimming Ostrich, while its resemblance to modern diving birds was based upon adaptive characters. On reflection, however, I concluded that such a statement would doubtless lead to useless discussion, especially on the part of those who had no new facts to offer, and, having myself more important work on hand, I remained silent, leaving to future discoveries the final decision of the question at issue.

It is an interesting fact that this decision is now on record. A quarter of a century after the discovery of *Hesperornis*, and a decade and a half after its biography was written in the Odontornithes, its true affinities, as recorded in that volume, are now confirmed beyond dispute. In the same region where the type specimen was discovered, a remarkably perfect *Hesperornis*, with feathers in place, has been found, and these feathers are the typical plumage of an Ostrich.*

Yale University, New Haven, Conn., March 16th, 1897.

* Williston, Kansas University Quarterly, vol. v, p. 53, July, 1896.

SCIENTIFIC INTELLIGENCE.

I. Geology and Mineralogy.

1. *Vertebrate Fossils of the Denver Basin;* by O. C. Marsh. Extract from Monographs of the United States Geological Survey, vol. xxvii, pp. 473–550, 80 figures in text, and plates xxi–xxxi.—Denver is in the midst of a number of geological horizons which are capable of exact determination from the vertebrate fossils they contain. These beds have been made the subject of special study by the author of this paper, and the separate horizons have each received distinctive names based upon the presence of a characteristic vertebrate genus. The Mesozoic and Cenozoic include essentially all the strata of the Denver Basin, and the oldest rocks positively identified belong to the Jurassic, of which the Hallopus, Baptanodon, and Atlantosaurus beds are recognized. The chief vertebrate horizons of the Cretaceous in this region include the marine Pteranodon and the fresh-water Ceratops beds. The Eocene is absent on the eastern slopes of the Rocky Mountains here and to the north, but is known farther south. The Miocene and Pliocene are present, the former containing the Brontotherium, and the latter, the Pliohippus beds. After the geological discussions, there follows a description of the leading mammalian, avian, and reptilian forms of each horizon, accompanied by figures in the text and restorations of the complete animals on the plates.

The object of the chapter, as stated by the author, is to indicate, first, the relative position of the various horizons containing vertebrate faunas; second, to give accurate figures of the important type specimens, so that the strata containing their remains may be thus identified; and, in conclusion, to state briefly something of the life-history of these extinct animals, and under what conditions they lived and died. C. E. B.

2. *Geology of Minnesota, Vol. III, Part 2, of the Final Report. Paleontology;* by E. O. Ulrich, John M. Clark, Wilbur H. Scofield, N. H. Winchell. pp. lxxxiii–cliv, 475–1087, 1897.—An introductory chapter gives a correlation of the Lower Silurian deposits of the upper Mississippi province, revising to some extent the previously published correlation on the basis of the total evidence of stratigraphy and paleontology. The Trenton period is represented by the *St. Peters sandstone* of the Chazy group; the *Buff limestone*, *Vanuxemia* and *Stictporella beds* of the Stones River group; the *Rhinidictya*, *Ctenodonta*, *Phylloporina* and *Facoid* or *Orthis Spectinella beds* of the Black River group; the *Clitambonites*, *Fusispira*, and *Maclurea beds* of the Trenton group (galena, limestone and shale, Nashville group). The Hudson River or Cincinnati period (the authors prefer the latter name, but have adopted the former) is represented in the Minnesota area by rocks referred to the Utica group, and to the Richmond group. The total number of species recognized in the

Trenton period strata is 696, and 113 species from the rocks of the Hudson River period.

The body of the volume consists of exhaustive descriptions and illustrations of the fossil species of the Lower Silurian (Ordovician) formations of Minnesota. The chapter on the Lamellibranchiata is by E. O. Ulrich; the author has succeeded in figuring a good number of interiors and hinge teeth of these ancient types. The Ostracoda are also described by Ulrich. The chapter on Trilobites and Cephalopoda are by J. M. Clark.

Mr. Ulrich and the late Mr. W. H. Schofield (who died during the preparation of the work) prepared the chapter on the Gastropoda. The large number of forms related to Bellerophon and Bucania, and to Pleurotomaria and associates are worthy of particular notice. The authors propose the erection of a new suborder, *Bellorophontacea*, to include twenty-three genera divided into the following five families; viz.. Cyrtolitidæ, Protowarthiidæ, Bucaniidæ, Bellerophontiidæ and Carinaropsidæ. A number of new genera are described. Under the Pectinibranchiata the new suborder *Eotomacea* is proposed to include the families Rhaphistomidæ, Pleurotomariidæ, Euomphalidæ, Trochidœ, and some others. In this suborder a large number of new species and several new genera are described from the Minnesota material. The illustrations are numerous and well done; and the work is a rich contribution to knowledge of the Ordovician forms of North America. H. S. W.

3. *Geological survey of Alabama; Report on the valley regions of Alabama (Paleozoic strata)* by HENRY MCCALLEY, Assistant State Geologist. Part I. The Tennessee valley region. pp. 1–436, with illustrations, 1896.—The report contains a valuable amount of information regarding the local details of stratigraphy and the geological products of economic importance.

4. *Catalogue and index of contributions to North American Geology, 1732–1891;* by N. H. DARTON. Bull. No. 127, U. S. Geol. Surv., pp. 1–1045. 1896.—This index is a work which will be of the greatest time-saving value to all students of North American geology. The literature is recorded alphabetically under both author and subject primary titles, and under each primary title the entries are arranged secondarily in chronological order.

Papers and books purely paleontologic or purely mineralogic are not included. It would not be surprising if omissions occur even in a work so carefully done as this one, and the author requests readers to send additional references or information for a supplement to him, care of the United States Geological Survey, Washington, D. C. H. S. W.

5. *Description géologique de la partie sud-est de la 14-me feuille de la vii zone de la carte générale du gouvernement Tomsk (Feuille Balachouka)*; par P. VENUKOFF (in Russian with French résumé), pp. 1–151. 1896.—The formations described in this paper include limestone formations containing an abundant characteristic Neodevonian fauna, above which are Carboniferous

limestones containing abundant characteristic Carboniferous faunas; lists of both of the faunas are given. H. S. W.

6. *Catalogus Mammalium tam viventum quam fossilium*, a Dr. E. L. TROUESSART. *Nov. ed.* (*prima completa*). *Fascic 1. Primetes, Prosimiæ, Chiroptera, Insectivora*, pp. 1–218 (Berlin: R. H. Friedländer & Sohn), 1897.—This new edition of Trouessart's list professes to be complete, and offers in a compact form a reference catalogue of all the known species, fossil and living, of mammals of the first four orders, with bibliography and geographical distribution of each species.

7. *Congrès géologique international.*—A second circular has been issued by the committee announcing the dates of the meeting and of the several excursions. The session of the Congress will be held at St. Petersburg, beginning Aug. 29th and closing Sept. 4th. The excursions before the meeting are three: A, to the Ural mountains, departing from Moscow July 30th and returning to St. Petersburg Aug. 26th; B, in Esthonia Aug 13th to Aug. 27th; C, excursion in Finland, Aug. 21st to Aug. 28th, starting at Helsingfors. After the meeting the grand excursion to the Caucasus will depart from St. Petersburg Sept. 5th, by three different routes, the three parties coming together again at Wladikavkaz about Sept. 15th, and the excursion ends at Sébastopol, Oct. 4th.

Each member attending the Congress will receive a free pass entitling him to transit in first class cars over the Russian and Finnish railroads. The other expenses connected with the several excursions are estimated at 400 francs for the Ural, 135 fr. for the Esthonia, and 50 fr. for the Finland excursions. The expense for the grand Caucasus excursion will be 665 francs for the main part and additional amounts (40 to 270 fr.) for the several branch excursions arranged in connection with it. The address of the local secretary is A. O. Michalski, Comité Géologique, St. Petersburg, Wassili Ostrow, 4^{me} Ligne, Russia. H. S. W.

8. *Geology of Santa Catalina Island;* by WM. S. TANGIER SMITH (Proc. Cal. Acad. Sci., Third Ser., Geol., vol. i, No. I. 1897. 8vo, 71 pp., 3 pl.)—The excellent and enthusiastic work in detailed geology, petrography and mineralogy which is being carried on in the California Coast region by an earnest group of young workers under the guidance of Prof. A. C. Lawson, is well known. The present paper adds another chapter to the work already done and we trust another worker in this great field of hidden wealth.

The author describes the general features of the island and especially the eruptive rocks which make up the greater part of its area; of these careful petrographic descriptions and analyses are given. The series comprises diorites, porphyrites, andesites and rhyolite; areas of tuffs, schists and quartzite are also studied, and the work concludes with an outline of the geologic history of the island. An excellent colored map is added. L. V. P.

9. *Elementary Geology;* by RALPH S. TARR. pp. 499. New

York 1897 (The Macmillan Co.; price $1.40).—The author has here attempted to present the subject of geology in a form suitable for the comprehension of quite elementary students; he dwells especially upon the dynamical side of the subject, rightly regarding the full treatment of historical and stratigraphical geology as belonging to an advanced course of study. In many respects he has done his work well, but it is to be regretted that he has allowed himself to be careless in writing at a number of points, and, moreover, that occasional errors in the names of fossils and other blemishes come in, which are unfortunate in the case of a book which is to go into the hands of young students.

It is hardly allowable, for example, even in popular language, to speak of coral mud as "clay." Further, the proper use of such terms as period, age, epoch, etc., in geological chronology, is a matter to which geologists have given much thought, and it is unfortunate that they should be used by the author with so little discrimination, different terms being used for the same divisions even in the course of a single sentence. Other points might be mentioned; for example, on page 410, No. 1 of fig. 235 is called a "brachiopod" but is named "Aulopora arachnoidia"; the latter perhaps referring to the label, and the former to the specimen with which it was found.

The author has evidently made an effort to secure original illustrations on a liberal scale, and many of the reproductions from photographs can be highly commended, but not a few of the figures, especially in the early part of the book, bear (as printed) little or no resemblance to the objects which they are designed to illustrate. The fossils, too, which are figured in the latter part of the book are poorly selected and give but little indication of the distinguishing characters which they are intended to represent.

10. *A Catalogue of the Minerals of Tasmania;* by W. F. Petterd. 103 pp. Launceston, 1896.—This catalogue is an extension of an earlier one published in 1893. It enumerates some 269 species which have thus far been identified among the mineral products of Tasmania. Among these are a number of considerable rarity, as crocoite, vanquelinite, eudialyte, etc., which it is interesting to learn of as occurring in a new locality. We note the following names which are now introduced into the science. Dundasite, from a qualitative analysis, is inferred to be a hydrated carbonate and phosphate of lead and aluminum. It forms small spherical aggregates with radiated structure, and is milky white in color, except on the surface, which is yellow-brown. It was obtained from the Adelaide mine, Dundas. Heazlewoodite is a sulphide of nickel and iron, related to pentlandite but apparently not to be identified with it. According to some assays, it contains 38% of nickel. Weldite is a silicate of aluminum and sodium from the Weld River. It occurs in white masses; hardness = 5·5; specific gravity = 2·98. It was announced by F. M. Krausé in 1884.

11. *The Production of Precious Stones in 1895;* by George

F. KUNZ.—This interesting chapter from Part iii of the Seventeenth Annual Report of the Geological Survey (Mineral Resources of the United States) has been issued in separate form.

II. BOTANY AND ZOOLOGY.

1. *A Manual and Dictionary of the Flowering Plants and Ferns;* by J. C. WILLIS, M.A., Director of the Royal Botanic Gardens, Ceylon. In two volumes, 8vo. pp. 653.—In these two handy volumes have been brought together, in an orderly and convenient form, the principal facts and cardinal principles in regard to the more important ferns and flowering plants. It is seldom that such discrimination in selection, such skill in arrangement and such perspicuity in statement, are conjoined: each one of these factors is so pronounced in the work in hand that it would, even if taken alone, make the treatise valuable; taken together, they place it in advance of any work in the same field.

Part second was written first. It comprises descriptions of the largest genera and of those of greatest importance in their relations to men, together with excellent accounts of the chief orders arranged alphabetically. Besides all this, small genera are referred to and assigned to their proper orders. Morphology, especially that which deals with adaptive mechanisms, Classification, Distribution and Economics, are presented in sufficient detail, and in an interesting way. But the author was not content with this, and therefore he prepared a supplementary volume, numbered one, which constitutes a remarkable introduction to the alphabetical portion. In this introductory part, he places the reader in possession of the essential terminology of modern botany, and carries him along through the difficulties presented by variation, and evolution in general, until he brings him face to face with modern classification. Thence he conducts the reader intelligently through the most telling part of geographical botany, and explains the relations of adaptation to the whole.

We are not inclined to find fault even with the rather too technical aspect of a few of the pages, for we have seen the experiment tried of giving the work as a whole to a reader not particularly interested in botany, who wished to glance at the author's statement of natural selection. The reader did not leave his examination of the volume until he had made himself familiar with the whole, and this, it must be confessed, is a good test. The treatise is a distinct and valuable addition to our works of reference. G. L. G.

2. *Studien ueber den Hexenbesenrost der Berberitze;* by DR. JAKOB ERIKSSON.—In this paper, published in the Beiträge zur Biologie der Pflanzen, vol. viii, are given some curious facts in regard to the development of *Aecidium Magellanicum*, which was first described on *Berberis ilicifolia* in South America, but has since been observed on species of Berberis in Europe and differs from the ordinary *Aecidium Berberidis*, which is a stage of

Puccinia graminis. It had been suspected that *Aec. Magellanicum* was a species which was perennial on barberries, although by some mycologists it was supposed to be associated with a Puccinia which grows on *Avena elatior.* By his cultures made at the experiment station near Stockholm, Prof. Eriksson has shown by inoculations that, although *Aec. Magellanicum* is really a stage of the rust of *Avena elatior* to which he gives the name of *Puccinia Arrenatheri,* it is also true that two stages, the aecidium and the teleutospores, including the uredo, may be propagated perennially independently of one another on Berberis and Avena respectively. In other words the two stages of development are facultative rather than essential. When, however, the aecidium-stage is propagated perennially the normal period of incubation is much lengthened, a period of from three to four years being required. W. G. F.

3. *Phycotheca Borealis-Americana,* Cent. vi; by Messrs. Collins, Holden and Setchell—The last fascicle of this important series contains a smaller proportion than usual of fresh-water species, the marine species preponderating. Among the rarities we may mention *Phycocelis maculans, Entoderma Wittrockii* and *Kallymenia perforata.* W. G. F.

4. *Analytic Keys to the Genera and Species of North American Mosses;* by Charles Reid Barnes and Fred DeForest Heald. Bulletin University Wisconsin, Science Series I i–x, 157–368, Madison, Dec., 1896.—This is an extension and revision of the *Artificial Keys to the Genera and Species of Mosses recognized in Lesquereux and James' Manual of the Mosses of North America* issued by Prof. Barnes in May, 1890, a work which proved to be of great practical service to students of our mosses. The revised edition includes an Appendix of 116 pages, which gives the descriptions of species and varieties published since the issue of Lesquereux and James's Manual in 1884 and before January 1896. The large number of species given in the Appendix, 603 in all, shows the great activity of bryologists in recent years, and the incorporation of them in the *Analytic Keys* will greatly facilitate the study of our moss-flora, for only a small number of specialists have access to the original descriptions. W. G. F.

5. *Index Desmidiacearum citationibus locupletissimus atque Bibliographia;* by C. F. O. Nordstedt. Berlin. pp. 310, 4to. —This Index well deserves the name "locupletissimus," for it contains not far from 1200 titles in the Bibliographia. It may practically be called a complete index; at least, it would be difficult to imagine one more complete. The species are arranged alphabetically by specific names and under each specific name the generic names, when there are more than one, are arranged alphabetically with the reference to the literature arranged chronologically. By means of letters it is indicated whether any reference cited gives a description, figure, measurement, etc. The amount of labor required to prepare the Index must have been enormous and

the typography is excellent. The great value of this work, indispensable to algologists, lies in the fact that it is not a catalogue prepared by a professional catalogue-maker, but an Index arranged by an expert in the subject who has a thorough practical acquaintance with the Desmids themselves. W. G. F.

6. *Die Protrophie;* by Dr. Arthur Minks. Berlin, 1896. pp. 247, 8vo.—Early in 1896, Dr. Minks gave a preliminary account in the Oester. Bot. Zeit. of what he terms "eine neue Lebensgemeinschaft." The present volume gives a detailed account of his discovery. The discovery may perhaps better be styled an invention, for the name protrophie designates a condition previously recognized in certain lichens, as *Biatora intumescens*, by which they at first exist in a parasitic condition on other lichens and, after destroying them, lead an independent existence. To this condition Malme, who is a Schwendenerite, gave the name of Antagonistic Symbiosis. Minks, who is far from being a Schwendenerite, calls it Protrophie. By those who do not feel called upon to advocate any particular hypothesis, it might be supposed that it would be as well to speak of it simply as a case of parasitism, and in some, at least, of the cases cited by Minks the inquiry seems pertinent whether the protrophic plants should not be called fungi rather than lichens. On that point, however, discussion is out of the question, because what is or is not a lichen is a point on which lichenologists and mycologists have never been able to agree. W. G. F.

7. *The supposed great Octopus of Florida; certainly not a Cephalopod.*—Additional facts have been ascertained and specimens received, that render it quite certain that this remarkable structure is not the body of a Cephalopod. It was described by me, in the February number of this Journal, as the body of an Octopus,* from the examination of a number of photographs, and the statement made to me that, when it was first cast ashore, stumps of arms were found adherent to one end, one of which was said to have been 36 feet long.† Subsequently, when it was excavated and moved, this statement proved to be erroneous. Apparently nothing that can be called stumps of arms, or any other appendages, were present. Folds of the integument and muti-

* Many other zoölogists who examined the photographs held the same opinion. Some of those who have seen the samples of integument sent to me still believe that the specimen may be the body of some unknown genus of Cephalopods, allied to *Octopus*. But the thick integument of a Cephalopod is necessarily muscular and highly contractile, while in this creature it is elastic and resistant, and not at all contractile. Therefore I cannot refer it to that group, after having examined this structure.

† The following is the written statement made by Mr. Wilson to Dr. Webb, in regard to the "arms" that he found when it first went ashore: "One arm was lying west of body, 23 feet long; one stump of arm, west of body, about 4 feet; three arms lying south of body and from appearances attached to same (although I did not dig quite to body, as it laid well down in the sand, and I was very tired), longest one measured over 32 feet; the other arms were 3 to 5 feet shorter." Soon after this examination the specimen went adrift in another severe storm and was again cast ashore two miles farther south, which will probably account for the loss of these supposed arms.

lated and partly detached portions may have been mistaken for such structures. No bones or other hard parts were found in it.

Dr. Webb has recently sent to me several large masses of the integument of the creature, preserved fairly well in formalin. These masses are from 3 to 10 inches thick, and instead of being muscular, as had been thought, they have a structure similar to the hard, elastic variety of blubber-like integument found on the head of certain cetaceans, such as the sperm whale. They contain very little oil and cannot be called true blubber. They are firm, very tough and elastic, and composed mainly of much interlaced fibers and large bundles of tough, fibrous, white connective tissue. They are difficult to cut or tear apart, especially where indurated by partial drying. Some large irregular canals permeate the inner and less dense portions of the thick masses. These may have contained blood vessels originally. From the inner surface of some of the pieces large cords of elastic fibers proceeded inward. These now hang loosely from the masses of integument. Dr. Webb states that these were found attached on all sides to a long saccular organ, which occupied most of the central cavity of the great mass. No muscular fibers were present in the specimens sent. Perhaps the muscular tissues of the inner surfaces, if any were present originally, have decayed, but the tough fibrous mass does not show much decomposition. The outer surface shows in some places a tough, thin, gray, rather rough skin-like layer, that may be the remains of the outer skin. It looks a little like the skin of some fishes from which the scales have been removed. From these facts I am led to believe that the mass cast ashore is only a fragment, probably from the head, of some huge vertebrate animal, covered with a blubber-like layer of great thickness.

Although such an integument might, perhaps, be supposed compatible with the structure of some unknown fish* or reptile, it is certain that it is more like the integument found upon the upper part of the head of a sperm whale than anything else that I know. If we could imagine a sperm whale with the head prolonged far forward in the form of a great blunt, saccular snout, freely projecting beyond the upper jaw, and with a great central cavity, it might, if detached and eroded by the surf, present an appearance something like the mass cast ashore. It hardly seems possible, however, that the abruptly truncated and narrow snout of the common sperm whale could take on, even after being long tossed about by the waves, a form like this. No whaler who has seen it has recognized it as any part of a whale. It does not seem possible to identify such a large, hollow, pear-shaped sac, 21 feet long, with any part of an ordinary sperm whale unless its nose had become enlarged and distorted by disease, or possibly by extreme old age. No blowhole was discovered.

The specimen has now been moved several miles nearer to St. Augustine and enclosed by a fence to protect it from the drifting sand. It is likely to remain in nearly its present state for several months more.

A. E. VERRILL.

* The integument of *Orthagoriscus mola*, the great sun-fish, is very thick and elastic, but unlike this in structure.

III. Miscellaneous Scientific Intelligence.

1. *Lehrbuch der Allgemeinen Chemie;* von Dr. Wilh. Ostwald. Second edition, vol. ii. Part ii. Verwandschaftslehre. pp. 1–208 (Engelmann, Leipzig), 1896.—The present issue, the first of five installments, which when complete will conclude the present edition of the work, is devoted almost entirely to the history of affinity. Hardly anything remains of the previous edition except the arrangement. The whole work has been rewritten and numerous valuable additions in the shape of extracts from original memoirs have been inserted. Considerable space has been devoted to the work of Gibbs and van't Hoff, conspicuously marking the recent achievements in this branch of science, and the dissociation theory of Arrhenius receives its share of attention. The work comprises our complete knowledge of the doctrine of affinity, and is, like all other books from the pen of this talented author, a most valuable addition to scientific literature. B. B. B.

2. *Inorganic Chemical Preparations;* by F. H. Thorp. 8vo, pp. 238. Boston, 1896 (Ginn & Co.).—This important branch of chemical instruction doubtless deserves to be taught more generally and fully than is the case at present, and new aids to carrying out such instruction should be welcomed. The book under consideration gives 100 preparations, with directions which are generally very full and satisfactory. Much useful information is given concerning reactions, molecular weights, specific gravities of solutions and the solubilities of the products, etc. The preparations selected are the salts most used in the laboratory as reagents, or those of commercial importance. The raw materials required are, with few exceptions, inexpensive.

The quantities recommended in the book seem, in many instances, larger than the facilities of most laboratories would warrant and larger than the student would need to become familiar with the compounds. The number of preparations, consisting merely of the purification of commercial salts and which give but little variety of chemical methods, seems to the reviewer to be unduly large; but many instructive preparations are introduced, and with a proper selection of these a very satisfactory course could be carried out with the aid of this book. H. L. W.

3. *Tutorial Chemistry.* Part i. Non-metals; by G. H. Bailey. 12 mo, pp. 126. London (W. B. Clive; Hinds & Noble, 4 Cooper Institute, New York).—This little text-book possesses many admirable features. It is not overburdened with either facts or theory, but the fundamental principles of the science are clearly set forth and the number of facts presented seems well adapted for the needs of the beginner. The experiments, about 100 in all, are well chosen, and many of them show originality in their manner of presentation. A treatment of the subject of "chemical physics" is promised for the second part in connection with a study of the metals. H. L. W.

4. *Laboratory Manual of Inorganic Chemistry;* by R. P.

WILLIAMS. Ninth edition, 12 mo, pp. 100. Boston, 1896 (Ginn & Co.).—This little book, intended for young pupils, gives one-hundred exercises, to each of which a page of the book is devoted, a blank page being left opposite to this for notes. A short course in qualitative analysis is included. The directions given for experiments are generally clear and illustrated by appropriate cuts. The text is considerably marred by the use of many abbreviations, all of which are not self-evident. Pupils using this book would require much aid from their teacher, as equations are continually required although none are given in the book. H. L. W.

5. *Mountain Observatories in America and Europe;* by EDWARD S. HOLDEN, Director of the Lick Observatory. 77 pp. with 25 plates. Washington, 1896. (Smithsonian Miscellaneous Collections, 1035).—This is a very interesting discussion of the conditions required for successful astronomical work at high altitudes, followed by an account of the chief observatories already established in different parts of the world. The highest of these is the observatory of M. Janssen on the summit of Mt. Blanc, at an altitude of 15,780 feet. These accounts are illustrated by a large number of excellent and interesting plates.

6. *Essays by George John Romanes*, edited by C. LLOYD MORGAN. pp. 253 (Longmans, Green & Co.). 1897.—The republication of these essays, which originally appeared in several of the English and American reviews, will recall the versatile and attractive style of Romanes. The essays deal mainly with the philosophical aspects of biology; they are worth gathering in this permanent shape because of the importance of the problems, which the author handled with rare skill. H. S. W.

7. *North American Birds*, by H. NEHRLING, with thirty-six colored plates after water-color paintings by Prof. Robert Ridgeway, Washington, Prof. Goering, Leipzig, and Gustav Mutzel, Berlin. pp. 337–452, Milwaukee, Wis. (Geo. Brumder).—Part xvi completes this attractive work, to which attention has been repeatedly called hitherto. It is devoted to humming-birds, wood-peckers, kingfishers, etc., and closes with a list of plates and a general index.

8. *Das Klima von Frankfurt am Main;* im Auftrage des physikalischen Vereins bearbeitet von Dr. JULIUS ZIEGLER und Professor Dr. WALTER KÖNIG.—This is an exhaustive discussion of the meteorological conditions at Frankfort. It is accompanied by many tables, giving observations of barometric pressure, temperature, precipitation, winds, etc., extending over the period of the last fifty years. The most important of these results are also presented in graphical form in a series of ten plates.

OBITUARY.

Professor JAMES JOSEPH SYLVESTER, the eminent English mathematician, from 1876 to 1883 Professor at the Johns Hopkins University, Baltimore, died in London on March 15th, in his eighty-third year.

Roy Hopping,

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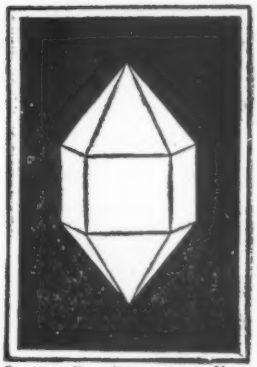

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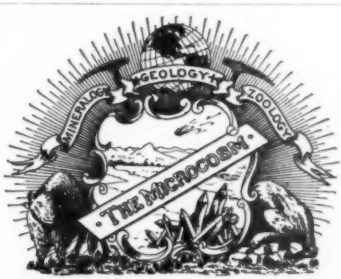

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Doña Inez (3),	10 to 15 "	Kessen,	15 "
Llano del Inca (3),	8 to 12 "	Pultusk,	13 to 15 "

(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci., Vol. 1. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894.

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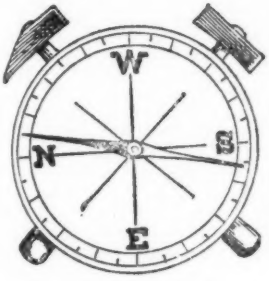

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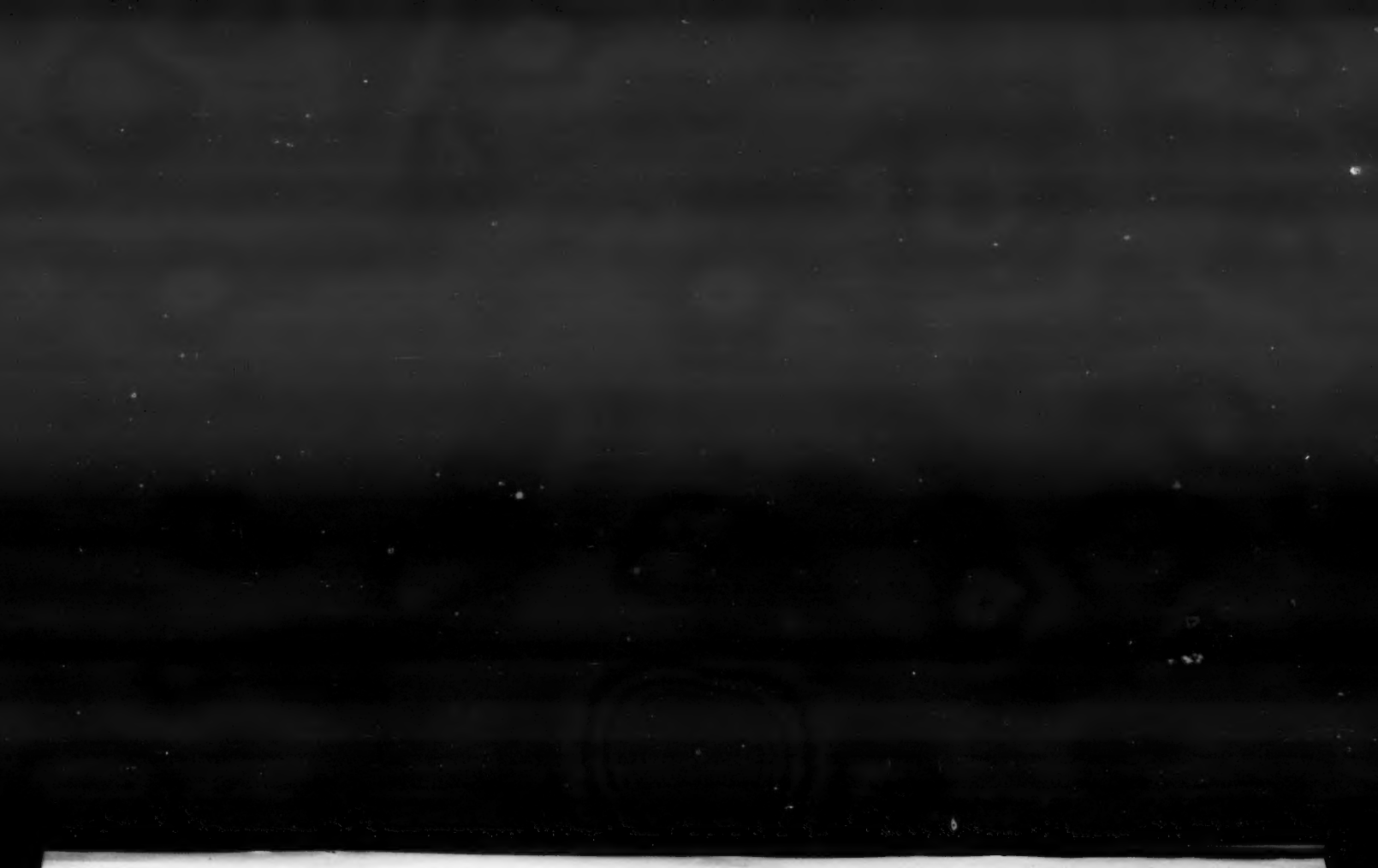
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